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2010-2011 YEAR BOOK

Carnegie Institution FOR SCIENCE

2010-2011







CARNEGIE INSTITUTION FOR SCIENCE

YEAR BOOK

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2010-2011 YEAR BOOK

The President's Report

July 1, 2010 - June 30, 2011

CARNEGIE INSTITUTION FOR SCIENCE

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About Carnegie

". . . to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind . . ."

The Carnegie Institution was incorporated with these words in 1902 by its founder, Andrew Carnegie. Since then, the institution has remained true to its mission. At six research departments across the country, the scientific staff and a constantly changing roster of students, postdoctoral fellows, and visiting investigators tackle fundamental questions on the frontiers of biology, earth sciences, and astronomy.

Carnegie Institution

Contents

The President's Commentary

Carnegie president
Richard A. Meserve
Image courtesy Jim Johnson

Andrew Carnegie enjoined the institution "[t]o discover the exceptional man in every department of study whenever and wherever found . . . and enable him to make the work for which he seems specially designed his life work." This injunction is regularly cited in these essays and, in fact, provides the touchstone that guides our recruitment and evaluation of our scientific staff. (Of course, we do not restrict ourselves as a result of Carnegie's use of a male noun and pronoun!) We seek scientists with the capacity to choose those scientific questions that can significantly advance humankind's knowledge and to devise an appropriate research approach for solving them. Indeed, one central component of scientific talent is the vision to choose the particular question and approach that offers the greatest opportunities for significant scientific gains.

In compliance with Carnegie's directive, we seek to enable each staff member to define his or her scientific agenda with as much freedom as we can provide. We are able to accomplish this, in part, through the expenditure of funds from our endowment, the source of about 50% of our budget. We thus stand apart from most other research institutions that are forced to undertake work for which funding can be obtained from federal or private sources. The institution's approach is made possible as a consequence of decisions by our board over the years to keep the institution small and thereby to sustain the capacity to support promising research, even if it is then unfashionable. Perhaps the paradigmatic example of the value of this strategy is reflected in the history of Carnegie's Barbara McClintock, whose work on "jumping genes" was not viewed as pathbreaking at the time it was undertaken, but which ultimately resulted in her Nobel Prize.

The injunction to support exceptional persons in their work may be interpreted by some to suggest that Carnegie scientists are constrained to pursue their ideas by themselves in the solitude of their individual laboratories. Certainly Carnegie's mission encompasses the support of such people. But the Carnegie directive does not limit the manner in which research is performed. Rather, the watchword is flexibility—a license for our scientists to pursue whatever means can best lead to scientific advance. Some work requires extensive collaboration and, as a result, many of our scientists work with a wide array of colleagues. Indeed, collaborative research is increasingly the norm at Carnegie and elsewhere.

I shall focus here on a few examples of many from which I could draw in which Carnegie scientists have played noteworthy roles in the assembly of collaborators

The tiny MESSENGER spacecraft was launched in August 2004 and, after a complex trajectory, was inserted into orbit about the innermost planet March 18, 2011. After only six months into its orbit, MESSENGER had already shown scientists that Mercury doesn't conform to theory.

Artwork courtesy NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

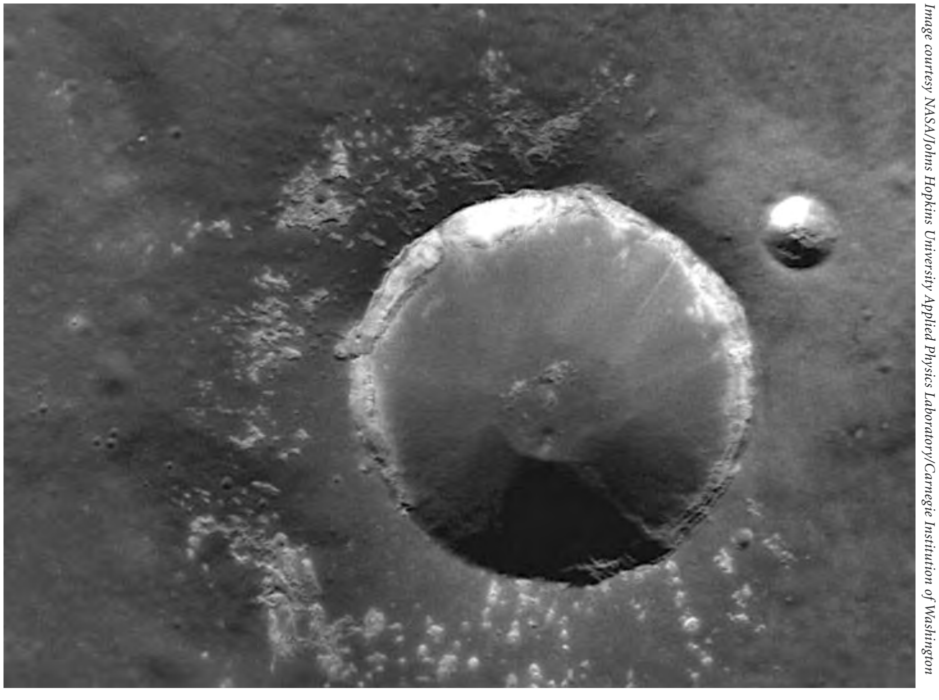


Image courtesy NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

(Above left) Then-director of the Department of Terrestrial Magnetism Sean Solomon, was selected by NASA to be the principal investigator of the MESSENGER mission to Mercury on July 7, 1999. He is shown here at a celebratory event with a model of the spacecraft.

(Above right) One of the major surprises from MESSENGER was the discovery of a class of shallow, irregular depressions, some with halos and bright interiors, which the researchers dubbed hollows. Here, hollows are sprinkled around the crater's smooth ejecta.

from other institutions around the world. I single out these examples because they show how Carnegie scientists have shaped fields and have spearheaded scientific projects that are vastly disproportionate to our commitment of treasure and staff.

MESSENGER

Carnegie's Sean Solomon, formerly the director and now a staff member at the Department of Terrestrial Magnetism (DTM), serves as the principal investigator of the NASA-funded MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission. Sean envisioned and has successfully shepherded a team involving dozens of institutions that has succeeded in placing the first spacecraft in orbit around our innermost planet. The craft was launched in August 2004 and made a flyby of Earth, two of Venus, and three of Mercury in order to enable a successful orbital insertion in March 2011. The scientific bounty from this mission, which is still being harvested, has already required a rewriting of scientific textbooks. The Mercury flybys enabled the imaging of portions of the planet that had never been seen in detail before, confirming the existence of widespread volcanism early in the planet's history. And many scientific surprises have arisen from the early months of measurements by the orbiting spacecraft.

The surprises include the discovery of higher abundances of sulfur and potassium than previously predicted. Because these volatile elements would have been driven off by previously presumed high-temperature events early in the planet's history, the measurements require a total rethinking of the theories surrounding the planet's formation. Images show a huge expanse of volcanic planes surrounding the north pole, including large volcanic vents. They also reveal an unexpected class of landforms of relatively young hollows that appear to have been formed by a previously unrecognized geologic process involving the loss of volatile materials. And Mercury's weak magnetic field has an unexpected structure—it is oddly offset toward the north, reflecting a lack of symmetry in the planet's core.

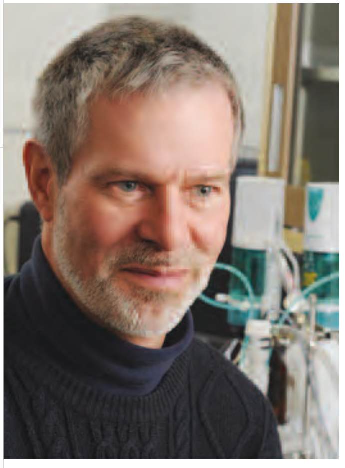
Although the spacecraft was originally funded for only one year of orbital observation, it has proven so successful that NASA has continued funding for a second year. The scientific returns to date include 25 papers published in *Science* magazine (out of 25 that were submitted!), including special sections devoted to MESSENGER on four occasions.[1] The project has already been memorialized through the issuance of a MESSENGER stamp by the U.S. Postal Service.

IPCC

Chris Field, the director of the Department of Global Ecology (DGE), is involved in a different sort of collaboration. Chris has been a major driver in the development of the discipline of global ecology, including especially the study of so-called emergent properties of ecosystems——properties that may not be intrinsic to individual components, but which emerge upon assembly at a large scale. His skill in studying complicated systems resulted in his involvement in the Intergovernmental Panel on Climate Change (IPCC), the United Nations-sponsored effort to develop a world-wide scientific consensus on various aspects of this critical global challenge. He served as a lead coordinating author for a chapter in the report issued in 2007——and was one of two Americans selected to represent the IPCC on its receipt of the Nobel Prize——and is now serving as cochair of Working Group II, the group that is studying impacts, adaptation, and vulnerability for the upcoming assessment. In that role, Chris is coordinating the efforts of over 300 talented scientists from around the globe in a comprehensive effort to distill what the science reveals, along with associated levels of uncertainty. The Technical Support Unit for this effort is located at DGE.

Over the decades Chris Field, director of the Department of Global Ecology, has been a major driver in the development of the discipline of global ecology. He became involved in the United Nations effort, Intergovernmental Panel on Climate Change (IPCC), to develop scientific consensus on various aspects of climate change. He served as a lead coordinating author for a chapter in the report issued in 2007 and is now serving as cochair of Working Group II. That group is studying impacts, adaptation, and vulnerability for the upcoming assessment.

[1] *Science 333*, September 30, 2011; *Science 329*, August 6, 2010; *Science 324*, May 1, 2009; and *Science 321*, July 4, 2008.



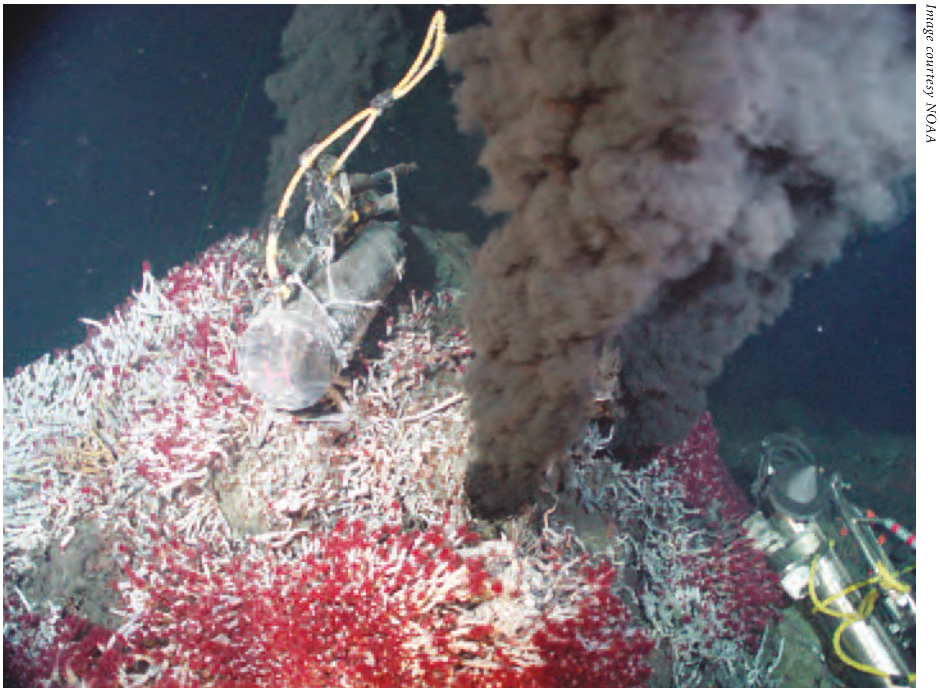


Image courtesy NOAA

(Above left) Geophysical Laboratory's Bob Hazen gave a lecture about life's geochemical origins, which became the catalyst for the interdisciplinary, international Deep Carbon Observatory project.

(Above right) In the late 1970s, scientists discovered that deep, cold, dark seafloor hydrothermal vents unexpectedly harbored life. Tube worms cover the base of this vent. Deep carbon researchers will hunt for signs of life even deeper within the Earth.

(Far right) This image shows liquid carbon at high pressures and temperatures.

The Working Group has recently released a special report on managing the risks of extreme weather events and disasters. Among its many interesting and important findings, the report concludes that weather extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases. The influences include increases in extreme daily minimum and maximum temperatures on a global scale, an intensification of extreme precipitation averaged across the globe, and increasing extreme coastal high water due to the increase in mean sea level. On the other hand, given the uncertainties in knowledge, the report provides low confidence in attributing changes in tropical cyclone activity to anthropogenic influences. This important report is a prelude to the release of a report on the full scope of the Working Group's efforts in 2014.

DEEP CARBON OBSERVATORY

Bob Hazen, a staff member in Carnegie's Geophysical Laboratory (GL), explores a wide-ranging set of scientific questions, including life's geochemical origins. As a result of his lecture on this subject, Bob was approached by Jesse Ausubel, a vice president at the Alfred P. Sloan Foundation, about a possible initiative to study the

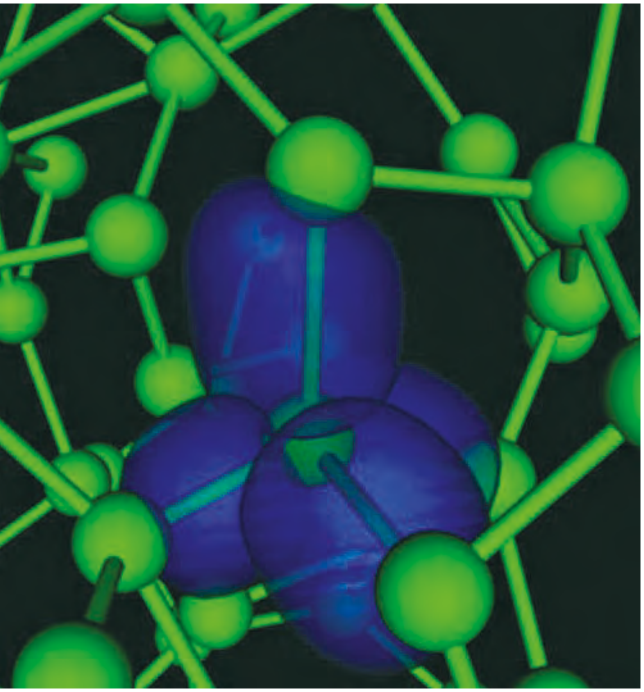


Image courtesy Alfredo Correa, Lawrence Livermore National Laboratory

origins of life in the Earth's deep subsurface. Bob recognized that biogenesis is just one part of the much larger challenge of understanding the deep carbon cycle—the movement of carbon over time from Earth's surface to its core. Bob thus responded with a counterproposal to launch a broadly interdisciplinary and international effort to characterize the role of carbon on the planet—its chemical, biological, and physical properties, where it is found and how it moves, and how it affects life on Earth.

With support from Sloan and others, a major effort to pursue that vision is now strongly underway. The effort has entailed the creation of four science directorates: deep carbon reservoirs and fluxes, deep life, deep energy, and the physics and chemistry of carbon. A secretariat was established at our Broad Branch Road campus, and workshops have been held around the world. In addition to numerous researchers from both DTM and GL, nearly 1,000 researchers from 60 countries are now engaged in the project. The effort is opening whole new vistas of previously unexplored science.

GMT

Carnegie has a long and distinguished history in astronomy, including a leadership role in the construction of many of the telescopes that have provided astonishing insights about the universe. For example, Carnegie's Edwin Hubble used a Carnegie telescope at Mount Wilson to discover that there are galaxies other than our Milky Way and that the universe was expanding. Two exceptional current-generation telescopes, each with a 6.5-meter primary mirror, are now in active use at Carnegie's Las Campanas Observatory in Chile. But, because larger and more capable telescopes invariably have led to astounding new discoveries, Carnegie's astronomers are already pursuing the construction of an even larger telescope, the Giant Magellan Telescope (GMT).

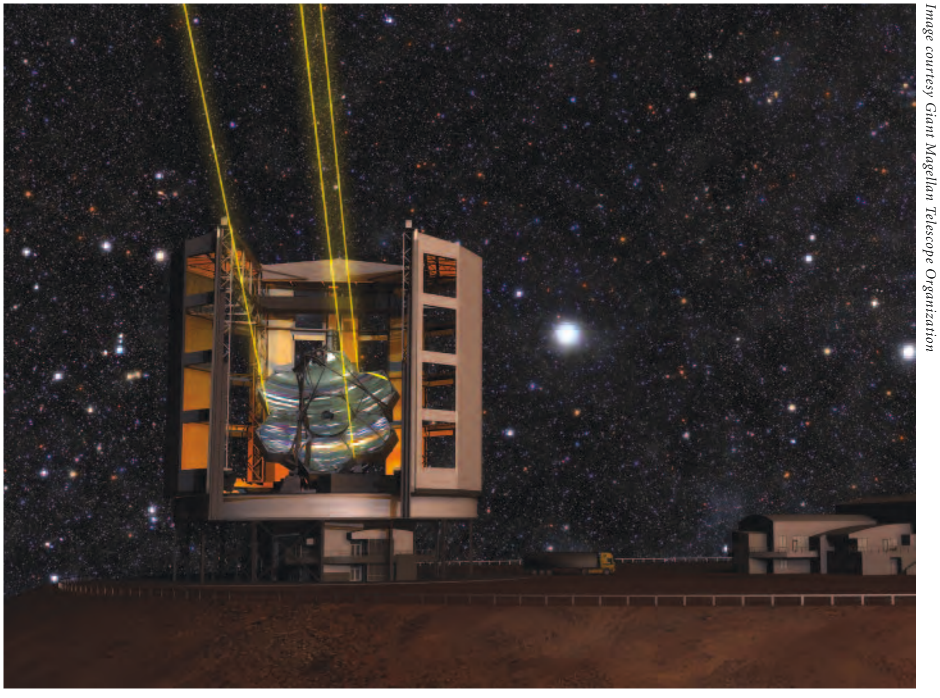


Image courtesy Giant Magellan Telescope Organization

(Above left) Wendy Freedman, the Crawford H. Greenewalt Chair director of the Carnegie Observatories, is also the chair of the Giant Magellan Telescope Organization.

(Above right) The Giant Magellan Telescope is expected to be operational in about a decade at Carnegie's Las Campanas Observatory in Chile.

The project has been spearheaded by Wendy Freedman, the director of the Carnegie Observatories and chair of the board of the GMT Organization. A consortium of U.S. and foreign entities has joined together to pursue the effort.[2] The aim is to construct and operate a telescope that will combine seven 8.4-meter primary mirrors to produce the equivalent of a telescope with a 25-meter aperture. The project promises to facilitate the understanding of the dawn of the universe, its large-scale properties, and the nature of the distribution of its matter and energy. The telescope will even allow the imaging of extrasolar planets, possibly allowing the discovery of life elsewhere. The GMT promises to open the next chapter of our understanding of the universe.

CHALLENGES

These large collaborations reflect the application of a 21st-century mechanism for the accomplishment of Carnegie's vision of supporting exceptional people in the pursuit of cutting-edge science. Of course, this vision requires the expenditure of resources. Carnegie's principal sources of funding are our endowment, federal grants, and awards from foundations and individuals. In light of the continuing economic turmoil, a discussion of our funding challenges has been an element of

[2] The GMTO partners are Astronomy Australia Ltd., the Australian National University, Carnegie Institution for Science, Harvard-Smithsonian Center for Astrophysics, Korea Astronomy and Space Science Institute, the University of Texas at Austin, Texas A&M University, the University of Arizona, and the University of Chicago.

my commentaries for several years. Unfortunately, this year is not one in which I can depart from the trend.

The endowment achieved an all-time highest valuation of $870 million in June 2008. It declined significantly in fiscal year 2009 to a low of $609 million, but has climbed back to $792 million at June 30, 2011. With guidance from our Finance Committee, we have achieved returns that exceed the State Street benchmark for endowments and foundations over the one-, two- and five-year periods, including a 22.7% return in the fiscal year encompassed by this Year Book. But, given the need to balance current and future needs, the endowment gains, although encouraging, cannot be the sole source of significant new funds.

FISCAL YEAR END	MARKET VALUE IN MILLIONS
6/30/2002	502
6/30/2003	526
6/30/2004	581
6/30/2005	648
6/30/2006	726
6/30/2007	832
6/30/2008	870
6/30/2009	636
6/30/2010	692
6/30/2011	792

We are fortunate that new support provided by federal and private grants and contracts has grown over fiscal year 2010-11 by $2.3 million to $44.2 million, providing a helpful inventory of funding over the next several years. This success is a testament to the skills of our scientists. Clearly, however, we should anticipate and prepare for the significant likelihood that federal support for science may decline in future years. The Budget Control Act enacted in connection with the increase in the federal debt ceiling requires additional budget cuts totaling $1.2 trillion over the next decade, and science funding from the federal government will no doubt suffer.

Nonetheless, I remain confident that the Carnegie scientists will continue to increase the storehouse of scientific knowledge through these tough economic times. Although the Carnegie departments are small by most measures, they are large in terms of their cutting-edge scientific output (as reflected, for example, by the listing of scientific publications elsewhere in this Year Book). We will continue to fulfill Andrew Carnegie's admonition to "encourage investigation, research, and discovery." The mysteries that can be unraveled by science are many and we pledge to continue to solve them.

Richard A. Meserve

Carnegie Friends

Annual Giving

Gifts were received between July 1, 2010, and June 30, 2011.

The Barbara McClintock Society

An icon of Carnegie science, Barbara McClintock was a Carnegie plant biologist from 1943 until her retirement. She was a giant in the field of maize genetics and received the 1983 Nobel Prize in Physiology/Medicine for her work on patterns of genetic inheritance. She was the first woman to win an unshared Nobel Prize in this category. To sustain researchers like McClintock, annual contributions to the Carnegie Institution are essential. The McClintock Society thus recognizes generous individuals who contribute $10,000 or more in a fiscal year, making it possible to pursue the highly original research for which Carnegie is known.

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Coulombe Family Trust
The Crystal Family Foundation
Damel Investors LLC
Ernst Charities
GrassRoots Biotechnology
Hicks Family Charitable Foundation
The Holaday Foundation
Laubach Family Fund
Linden Trust for Conservation
Lutron Foundation
McClelland Living Trust
Robert W. and Gladys S. Meserve Charitable Trust
Mulago Foundation
Northrop Grumman
Omenn-Darling Family Advised Fund
Pfizer Foundation Matching Gifts Program
Prince Charitable Trusts
Roxiticus Fund
Syntris Business Systems, Inc
T. Rowe Price Foundation
The Lee and Carol Tager Family Charitable Fund
VWR Charitable Foundation
The Wachovia Wells Fargo Foundation
The Weathertop Foundation
The Zoback Trust

★ *William Ian Mackenzie Turner, Jr.*

William Ian Mackenzie Turner, Jr.

Canadian Bill Turner joined the Carnegie board in 1990 and has served on practically every board committee at one time or another. With his mechanical engineering degree from the University of Toronto, his M.B.A. from Harvard, and his leadership positions with power, natural resources, and investment holding companies, Turner was a natural fit for Carnegie. He possesses the unusual ability to understand both the technical and business sides of the institution. Turner was vice chairman of the board from 1993 through 2006. Over the years he served on or chaired the Finance Committee, the Budget and Operations Committee, The Magellan Campaign Committee, the Employee Affairs Committee, the Nominating Committee, and the Research Committee.

For 20 years Turner has been a pivotal figure in all aspects of Carnegie's operations. But what sets him apart are his contributions to individual scientific projects. In 1993, Turner founded the Institution Carnegie du Canada. Each year Carnegie staff members have the opportunity to propose their research for grant awards. The Carnegie Canada board then annually awards grants to support individual scientists and programs that involve both Canada and the U.S. The collaborative grants span the spectrum of Carnegie science. In the 1990s and early 2000s Carnegie Canada awarded grants to Plant Biology to determine whether Canadian forests were sinks for carbon dioxide. Researchers at the Observatories benefited from a visiting Canadian astronomer's collaboration on the study of the age, structure, and dynamics of the universe. Terrestrial Magnetism received grants to understand why some continents are more stable than others and to search for extrasolar planets. Researchers at the Geophysical Laboratory (GL) received support to learn if gas hydrates had the potential to be energy sources.

Some examples of more recent Carnegie Canada support include fieldwork at Plant Biology to study how microbes living in extreme environments process phosphorus, an essential plant nutrient; fieldwork at GL to collect samples of ancient sedimentary rock in the Hudson Bay region; and a grant to Embryology to develop new tools to detect hormone activity in fat metabolism.

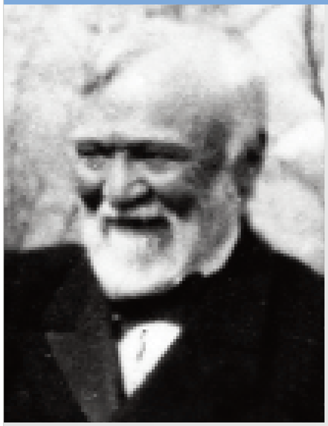
Many researchers have benefited from Bill Turner's unique generosity. The Carnegie scientists who have received grants not only greatly appreciate the support, they also appreciate his direct interest in their work. Carnegie is grateful for Turner's insights, guidance, hard work, and support for Carnegie science for over two decades. Turner and his wife, Nancy, are members of the Vannevar Bush Society.

Lifetime Giving Societies

The Carnegie Founders Society

Andrew Carnegie, the founder of the Carnegie Institution, established it with a gift of $10 million. Although he ultimately gave a total of $22 million to the institution, his initial $10 million gift represents a special level of giving. In acknowledgment of the significance of this initial contribution, individuals who support Carnegie's scientific mission with lifetime contributions of $10 million or more are recognized as members of the Carnegie Founders Society.

★ *Andrew Carnegie*

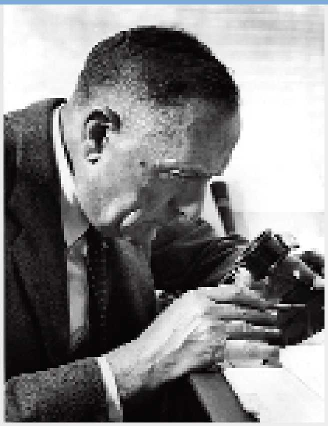


Caryl P. Haskins*
William R. Hewlett*
George P. Mitchell

The Edwin Hubble Society

The most famous astronomer of the 20th century, Edwin Hubble, joined the Carnegie Institution in 1919. Hubble's observations shattered our old concept of the universe. He proved that the universe is made of collections of galaxies and is not just limited to our own Milky Way—and that it is expanding. This work redefined the science of cosmology. Science typically requires years of work before major discoveries like these can be made. The Edwin Hubble Society honors those whose lifetime support has enabled the institution to continue fostering such long-term, paradigm-changing research by recognizing those who have contributed between $1,000,000 and $9,999,999.

★ *Edwin Hubble*

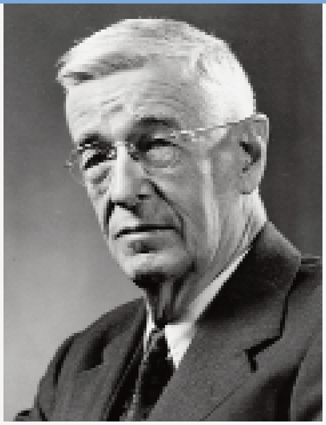


D. Euan and Angelica Baird
William and Cynthia Gayden
Michael and Mary Gellert
Robert G. and Alexandra C. Goelet
William R. Hearst III
Richard E. Heckert*
Kazuo and Asako Inamori
Michael Long
Burton and Deedee McMurtry
Jaylee M. Mead
Cary Queen
Deborah Rose, Ph.D.
William J. Rutter
Thomas and Mary Urban
Sidney J. Weinberg, Jr.*

The Vannevar Bush Society

Vannevar Bush, the renowned leader of American scientific research of his time, served as Carnegie's president from 1939 to 1955. Bush believed in the power of private organizations and wrote in 1950, "It was Andrew Carnegie's conviction that an institution which sought out the unusual scientist, and rendered it possible for him to create to the utmost, would be worthwhile . . ." He further said that "the scientists of the institution . . . seek to extend the horizons of man's knowledge of his environment and of himself, in the conviction that it is good for man to know." The Vannevar Bush Society recognizes individuals who have made lifetime contributions of between $100,000 and $999,999.

★ *Vannevar Bush*



Anonymous (3)
Bruce and Betty Alberts
Daniel Belin and Kate Ganz
Bradley F. Bennett*
Didier and Brigitte Berthelemot
Gary P. and Suzann A. Brinson
Donald and Linda Brown
Richard Buynitzky*
A. James Clark
Tom and Anne Cori
Jean and Leslie Douglas
Bruce Ferguson and Heather Sandiford
Stephen and Janelle Fodor
Robert and Margaret Hazen
Antonia Ax:son Johnson and Goran Ennerfelt
Paul A. Johnson*
Paul and Carolyn Kokulis
Gerald D. Laubach
Lawrence H. Linden
John D. Macomber
Steven L. McKnight
Richard A. and Martha R. Meserve
Al and Honey Nashman
Vera C. Rubin
Leonard Searle*
Christopher and Margaret Stone
William and Nancy Turner

Second Century Society

The Carnegie Institution is now in its second century of supporting scientific research and discovery. The Second Century Society recognizes individuals who have remembered, or intend to remember, the Carnegie Institution in their estate plans and those who have supported the institution through other forms of planned giving.

Anonymous
Bradley F. Bennett*
Louis and Lore E. Brown
Richard Buynitzky*
Eleanora K. Dalton
Nina V. Fedoroff
Kirsten H. Gildersleeve
Robert and Margaret Hazen
Paul A. Johnson*
Paul and Carolyn Kokulis
Gilbert and Karen Levin
Chester B. and Barbara C. Martin
Robert Metcalf
Leonard Searle*
Maxine and Daniel Singer
John R. Thomas, Ph.D.
Hatim A. Tyabji

** Deceased*
Members were qualified with records we believe to be accurate. If there are any questions, please call Irene Chen at 202.939.1122.

Honors & Transitions

Honors

Trustees/Administration

Trustee and astronomer **Sandra Faber** is the 2011 recipient of the Henry Norris Russell Lectureship of the American Astronomical Society.

Carnegie president **Richard Meserve** was the first recipient of the Vannevar Bush Dean's Medal from Tufts University in April 2011. He was also elected councilor of the National Academy of Engineering in May 2011.

Carnegie president emerita **Maxine Singer** received the Viktor Hamburger Outstanding Educator Prize from the Society for Developmental Biology in August 2010.

Embryology

Senior technician **Ona Martin** received the Carnegie Service to Science Award in May 2011.

Plant Biology

Director Emeritus **Winslow Briggs** was elected an Einstein Professor by the Chinese Academy of Sciences in October 2010.

Terrestrial Magnetism

Staff member **Paul Butler** was named a Fellow of the America Academy of Arts and Sciences in April 2011.

Business manager **Terry Stahl** received the Carnegie Service to Science Award in May 2011.

Vera Rubin received an honorary degree from American University in May 2010.

Transitions

Trustees/Administration

Senior trustee **Sidney J. Wienberg, Jr.,** died in October 2010.

The Carnegie board of trustees welcomed **Michael G. Wilson** to the board in May 2011.

Rick Sherman became Carnegie's chief advancement officer in February 2011.

Embryology

Nicholas Ingolia became a staff member on October 1, 2010.

Global Ecology

Anna Michalak was appointed a staff member June 1, 2011.

Observatories

Staff member emeritus **Allan Sandage** died November 13, 2010, at his San Gabriel, California, home.

Director Emeritus **Leonard Searle** died July 2, 2010, at his home in California.

Joshua Simon became a staff member September 1, 2010.

Jeffrey Crane joined the department as a staff associate in April 2010.

Plant Biology

New staff member **José Dinneny** arrived on June 15, 2011.

Terrestrial Magnetism

Matthew Fouch and **Diana Roman** joined as new staff members on June 27, 2011.

★ *Sandra Faber*

★ *Richard Meserve*

★ *Maxine Singer*

★ *Ona Martin*

★ *Winslow Briggs*

★ *Paul Butler*

★ *Terry Stahl*

★ *Vera Rubin*

★ *Sidney J. Wienberg, Jr.*

★ *Michael G. Wilson*

★ *Rick Sherman*

★ *Nicholas Ingolia*

★ *Anna Michalak*

★ *Allan Sandage*

★ *Leonard Searle*

★ *Joshua Simon*

★ *Jeffrey Crane*

★ *José Dinneny*

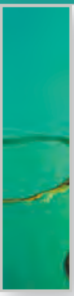
★ *Matthew Fouch*

★ *Diana Roman*

Research Highlights

Embryology

Deciphering the Complexity of Cellular, Developmental, and Genetic Biology



Tracking Cell Destiny

Egg and sperm beget a single cell that will eventually turn into a multicellular organism with vastly different cells and tissues. This journey begins when the single cell produces two cell "lineages": the outer cell lineage produces the placenta, and the inner cell lineage gives rise to all the body parts and derives embryonic stem cells (ESCs). How this "lineage specialization" happens has mystified scientists, but understanding this diversion will help to determine how the stem cells are able to turn into different types of tissues, which in turn could help determine how to reprogram adult cells back into stem cells for therapeutic purposes. Carnegie researchers Yixian Zheng and Katie McDole, in collaboration with Pablo Iglesias and Yuan Xiong at the Johns Hopkins Department of Electrical and Computer Engineering, and with the help of Carnegie's microscopy specialist Mahmud Siddiqi, have developed a new way to track cells in living mouse embryos as they develop. Surprisingly, they found that cells on the outside of the developing, ball-like embryo do not necessarily just turn into the placental lineage, as was previously thought.

A stumbling block to investigating early developmental decisions arises from the fact that embryos die when

This image shows ball-like, 32-cell-stage blastocyte embryos expressing dual fluorescently tagged proteins. Cells labeled red (mCherry) mark the cells' nuclei; green-fluorescing (GFP) cells mark cells destined for the outer cell layer.

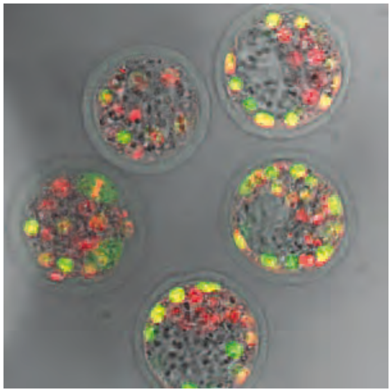


Image courtesy Katie McDole

This 3-D reconstruction shows a 64-cell-stage embryo expressing GFP in the cell's nucleus. Each nucleus is marked with different-colored spots representing each cell "lineage," starting from the 4-cell stage.

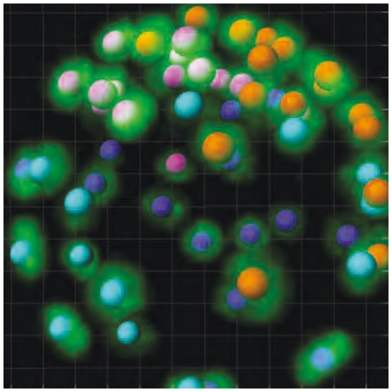


Image courtesy Katie McDole

This 3-D reconstruction of an embryo using the program IMARIS has blue spheres marking nuclear position and gray outlines representing the reconstructed surface of the embryo.

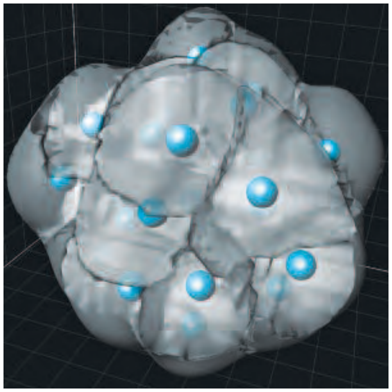


Image courtesy Katie McDole

exposed to light from a microscope for prolonged periods. Therefore, the team employed a different imaging technique that allows them to observe these lineage specialization events. They tag individual cells with fluorescent proteins to observe cell behavior and view them using two-photon microscopy coupled with sophisticated tracking algorithms.

With regular, one-photon, microscopy, the entire embryo is exposed to a high-energy beam of light. This light is toxic to the embryos and limits the time they can be imaged. In two-photon microscopy, the embryo is only exposed to high-energy light at the point of focus, leaving the rest of the embryo unharmed. In addition, the two-photon method has excellent depth of penetration, producing much better images. Among other surprises, the team discovered a unique population of embryonic cells that expose some of their surface to the outside but retain properties of inner cells and thus contribute to both the placental and embryonic lineages. They also found that the angle at which the cells divide, called cell cleavage, relates to cellular polarity, and described a previously unknown population of cells that change their cell fate through a unique migration event.

3-D Movies Advance Stem Cell Biology

To build and maintain a tissue, stem cells coordinate both the production of new cells on site and their migration to the location where they are needed. Understanding such active processes has been hampered by the need to fix, prepare, and stain cells for the microscope. Now Lucy Morris and Allan Spradling have developed a method for imaging stem cells in live tissue in the fruit fly *Drosophila*.

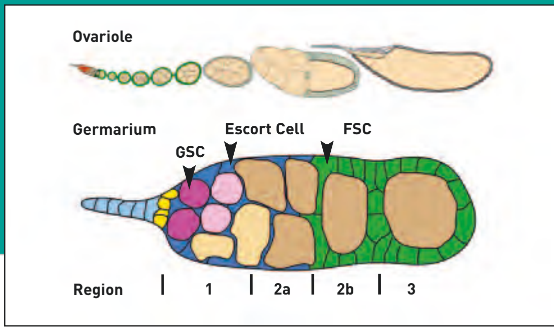
Image courtesy Connie Jewell

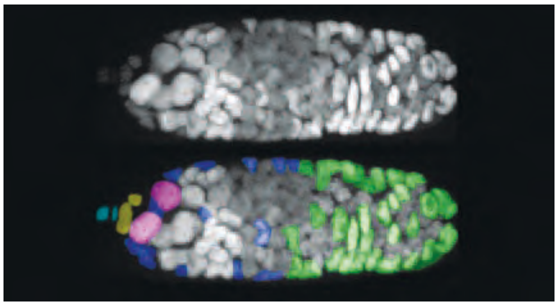
Lucy Morris in the lab

Human stem cells are harder to study than *Drosophila*'s. But studies of *Drosophila* can reveal how human stem cells can be used to treat injury, disease, and aging. This research is beginning to establish how both cell production and migration are regulated.

Drosophila ovarian stem cells generate egg precursors, known as follicles, within a small structure known as the germarium, which can be isolated and grown in culture. The germarium contains two types of stem cells: precursors to germ cells that will become the egg, and separate precursors that generate the epithelial cells of the follicle. How the germarium controls stem cells within special zones known as niches and how it orchestrates the movement of germ cell and follicle precursors remained unclear. Thin cells known as escort cells that are especially hard to study microscopically were likely involved. They wrap around early egg precursors from birth until they are packaged by a follicle cell layer.

Morris and Spradling were able to culture living germaria and record three-dimensional movie frames every

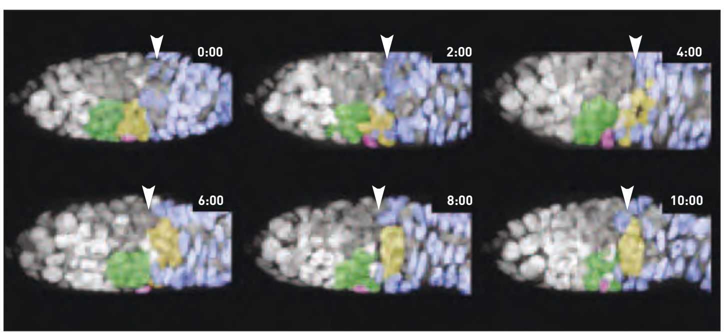


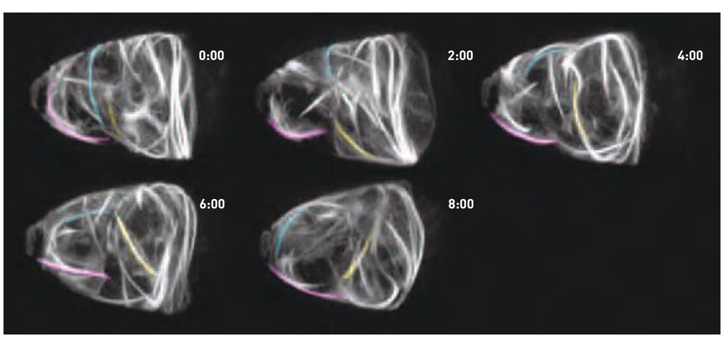


This diagram shows the four distinct subregions and the types of cells populating them in the *Drosophila* egg factory called the germarium. The photographs below show the actual cells. Immature egg cells are magenta in the lower one. Escort cells are dark blue and follicle cells are green.

10 minutes for 12 to 14 hours. The scientists used specific fruit fly strains genetically engineered to produce a fluorescent gene product that is observable in the living germarium. The scientists analyzed more than 120 cultures and recorded more than 1,300 hours of movies in all.

These studies helped characterize the follicle stem cell niche, whose origin has remained a major mystery. Previously, it was thought that escort cells are short lived, and move along with each developing egg cell. The movies showed that escort cells remain stationary while the egg assembly line passes by. Two stable escort cells contact follicle cell stem cells and likely serve as niche generators. Epithelial stem cell niches in humans remain poorly known, but they maintain tissues throughout our bodies, and their dysfunction promotes cancer. Thus, the work provides both new techniques and insights into regulatory mechanisms that ultimately influence our health and life span. □





(Top) The images in this sequence show how a grouping of immature egg cells (yellow) is initially associated with an escort cell (magenta). After 10 hours, the egg cell group migrates to a new location surrounded by follicle cells (blue). Meanwhile, the escort cell stays put and becomes associated with a younger group of immature egg cells (green).

(Bottom) Three escort cells (magenta, yellow, and turquoise) move in an otherworldly swirl of activity. The cells extend a thin membrane of ropelike structures called microtubules that surround the egg cell group. The scientists found that the escort cells do not adhere to and accompany the immature egg cell as it travels to the other end of the germanium, as most researchers believed. Instead, the escorts undergo dramatic shape changes and hand off the developing egg to other escort cells.

Geophysical Laboratory

Probing Planetary Interiors, Origins, and Extreme States of Matter

Minerals Love Life

It was not until recently that scientists even thought about how the mineral kingdom may have changed over time. Traditionally classified by composition, structure, and other features, the age of a mineral was usually ignored. That changed in the mid 2000s when Bob Hazen wondered why only 12 minerals existed in our corner of the cosmos before the Solar System formed 4.6 billion years ago and now there are more than 4,500. That sparked his pioneering research into mineral evolution. Surprisingly, he found out that the emergence of early life kindled some two-thirds of today's minerals. The work suggests that looking for specific minerals on other planets and moons could enhance the search for extraterrestrial life.

Hazen and colleagues have identified three eras of mineral evolution—early Solar System formation, when planets started to aggregate; the time when Earth's crust and mantle began to change; and the time when the Earth's surface interacted with biology. These three eras are further subdivided into 10 stages. But it was the Great Oxidation Event, about 2.4 to 2.1 billion years ago, that triggered an explosion of new minerals. That is when photosynthetic microorganisms began their rise, releasing oxygen, with the result that chemical reactions with oxygen and water at the near surface went wild.

The Big Bang produced just hydrogen, helium, and a smattering of lithium. Other elements formed over millions of years as giant stars produced other elements in their cores. When they exploded as supernovae, the first dozen minerals (mostly diamond, graphite, silicates, and oxides) crystallized. More than 250 different minerals formed in the earliest Solar System as dust and gas accumulated into planetesimals. On Earth, volcanoes, plate tectonics, water-rock interactions, and other geological changes 4.5 to 2.5 billion years ago led to the first continents and some 1,500 new minerals. But the emergence of life almost tripled the mineral population to some 4,000.

Currently, Hazen is looking at the first appearances of minerals containing specific elements. The research shows a notable increase in mineral diversity between 2.8 to 2.5, 2.0 to 1.8, and 0.43 to 0.25 billion years ago—when supercontinents were assembling and mountain building led to mineralization. Hazen recently found that many mercury-related

Bob Hazen conducts fieldwork in Montana.

Image courtesy Margee Hazen

Image used with permission from Ron Miller

Image used with permission from Elements

TABLE 1 THREE ERAS AND TEN STAGES OF EARTH'S MINERAL EVOLUTION

Era/Stage	Age (Ga)	Cumulative no. of species
Prenebular "Ur-Minerals"	>4.6	12
Era of Planetary Accretion (>4.55 Ga)		
1. Primary chondrite minerals	>4.56 Ga	60
2. Achondrite and planetesimal alteration	>4.56 to 4.55 Ga	250
Era of Crust and Mantle Reworking (4.55 to 2.5 Ga)		
3. Igneous rock evolution	4.55 to 4.0 Ga	350 to 500*
4. Granite and pegmatite formation	4.0 to 3.5 Ga	1000
5. Plate tectonics	>3.0 Ga	1500
Era of Biologically Mediated Mineralogy (>2.5 Ga to Present)		
6. Anoxic biological world	3.9 to 2.5 Ga	1500
7. Great Oxidation Event	2.5 to 1.9 Ga	>4000
8. Intermediate ocean	1.9 to 1.0 Ga	>4000
9. Snowball Earth events	1.0 to 0.542 Ga	>4000
10. Phanerozoic era of biomineralization	0.542 Ga to present	4400+

*Depending on the volatile content of the planet or moon

minerals first occur in formations dating from about 400 million years ago when the element interacted with organic matter introduced from the rise of the biosphere. These and other findings will be entered into a new Mineral Evolution Database under development, which no doubt will reveal other patterns.

Bonding Surprise

Understanding earthquakes, volcanoes, plate tectonics, and the evolution of the deep Earth requires determining how the small amount of water in deep materials behaves under high pressures and temperatures. Previous studies have looked at the changes that hydrogen and deuterium (hydrogen with an added neutron) undergo in systems of molecular hydrogen gas and water vapor

(Top) The Great Oxidation Event, which took place 2.4 to 2.1 billion years ago, witnessed an explosion of new minerals as the near Earth surface interacted with oxygen produced by photosynthetic microorganisms and water. Ferrous iron, which is present in black basalt (cooled rock from lava), became oxidized and rusty.

(Bottom) The table at left itemizes the eras, stages, time and number of minerals that have evolved on Earth over the past 4.6 billion years.

Geophysical Laboratory, *Continued*

and hydrogen gas and liquid water, but not for molecules in a supercritical fluid —a state of matter in which distinct gas and liquid phases are not found, such as in the deep Earth. Scientists Dionysis Foustoukos and Bjørn Mysen took a new approach to this old question.

As conditions vary in the Earth's interior, water and hydrogen molecules are incorporated in minerals, which greatly affect the chemical and physical properties of rocks and fluids coexisting deep inside the Earth. In particular, losses and gains of water, carbon dioxide, and hydrogen

Image modified by Dionysis Foustoukos. Used with permission from Free Software

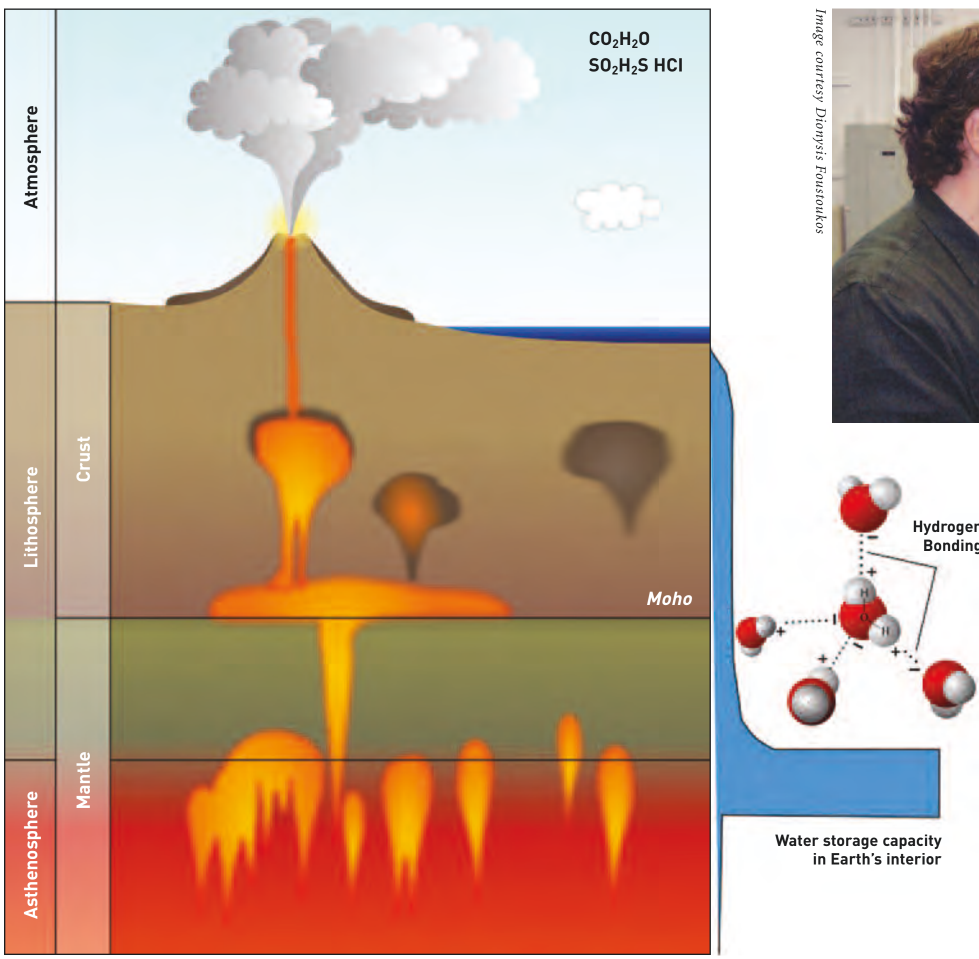


Image courtesy Dionysis Foustoukos

Dionysis Foustoukos in the lab

The water in the interior affects melting and mantle differentiation processes, and it has a profound effect on the distribution of volatiles—molecules that evaporate easily. Experimental studies addressing the strength of hydrogen bonding between water molecules shed light on the separation of isotopes between solid minerals and hydrous phases.

have significant effects on the evolution of magma—a molten rock mixture high in silica (silicon and oxygen).

The investigators mimicked lower-crust and upper-mantle conditions in the lab and analyzed different molecules using novel vibrational analysis techniques called Raman spectroscopy. They unexpectedly found that the hydrogen and deuterium systems underwent very different changes at high temperatures, which defies theory.

The researchers reacted solutions of normal water (H_2O) and so-called heavy water (D_2O) with titanium oxide to form molecules of hydrogen H_2, deuterium D_2, hydrogen and deuterium HD, and hydrogen, deuterium, and oxygen HDO. These are components that control the evolution of some mantle materials, such as methane. The scientists subjected the molecules to temperatures ranging from 570°F to 1470°F (300°C-800°C) under pressures from about 3,000 to 13,000 times atmospheric pressure (3-13 kilobars). The unexpected happened within the 1100°F to1400°F (600°C-800°C) range. Theory suggests that hydrogen and deuterium would have the same energy-exchange reactions and behave similarly at these conditions. But instead, the stable isotope distribution of hydrogen in the H_2O-H_2 and D_2O-D_2 systems differed greatly, meaning that hydrogen and deuterium would evolve differently in Earth's interior.

The researchers believe this result arises from surprising differences in hydrogen-bonding interactions of hydrogen versus deuterium in the fluid—information critical to mantle-water evolution models.

Harnessing Time

At first glance, materials science, environmental and planetary science, and defense and energy technologies seem to have little in common. But innovations in all these fields come from extreme temperature and pressure research. Now Alexander Goncharov and colleagues are taking their investigations of extreme states of matter to a higher level.

Traditionally, extreme pressure/temperature studies involve squeezing a small sample of matter between two diamond tips in a diamond anvil cell, then measuring the changes in structure, atomic behavior, electron movement, and other properties under different conditions. Over the decades, new materials have been created by this technique, and fundamental physical properties have been discovered. But until recently researchers have been unable to study material behavior over very short periods—billionths of a second and even shorter. These short snapshots are important for understanding materials as they transition from solids to liquids and gases, undergo fast chemical reactions, and engage in other activities.

These time limitations are now disappearing. Conventional so-called static compression methods involve a continuous heat source, often a laser, which bakes a sample in a traditional manner. Goncharov and team are exploring new dynamic methods, which use pulsed lasers to repeatedly heat and compress materials and examine them over very short intervals. Pulsed heating has several advantages: it can reach temperatures many times that of the old method, the short duration overcomes the problems of samples spreading out and inducing unwanted chemical reactions, and the dynamics of the processes can be investigated. It also happens to use much less power.

Carnegie leads new developments of ultrafast X-ray diffraction and imaging at the Advanced Photon Source in collaboration with the Carnegie-led High Pressure Collaborative Access Team (HPCAT) and the GeoSoil-

Geophysical Laboratory, *Continued*

Enviro Center for Advanced Radiation Sources (GSE-CARS). Recently, the Carnegie and Lawrence Livermore National Laboratory team used the new techniques to cold-compress hydrogen on an ultrafast timescale. At Carnegie's Washington campus, a suite of new optical instruments has been developed for ultrafast optical spectroscopy, imaging, and heat-flow measurements.

These advances will enhance understanding of unusual states, such as superconductivity. Studying electromagnetic and thermomechanical extremes will contribute to future fusion power, better steam turbines and jet engines, and fuel-efficient vehicles, among other applications. The short sampling intervals will also allow researchers to mimic chemical changes that come from meteoritic impacts on planetary surfaces, and the more extreme temperatures will better approximate conditions of planetary interiors, thereby enabling the study of their evolution. □

Image courtesy Alexander Goncharov

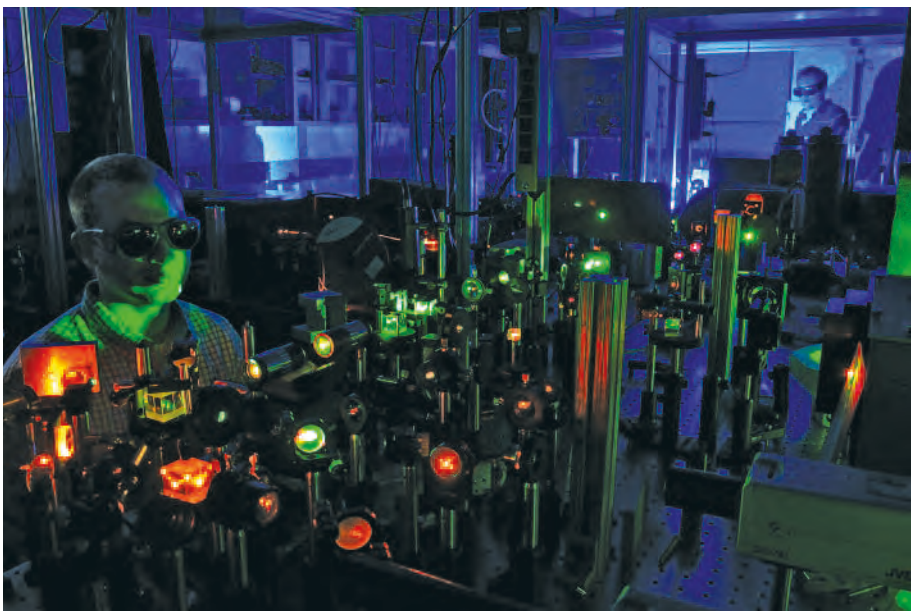
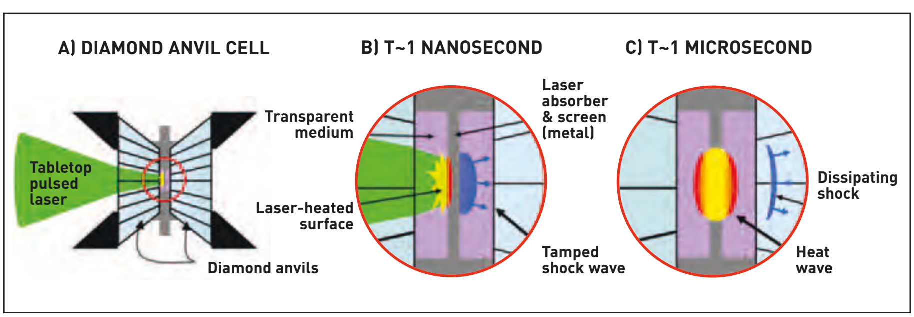


Image courtesy Alexander Goncharov



(Top) Members of the dynamic laser team include Goncharov postdoctoral associates D. Allen Dalton at left working with a supercontinuum laser beam. On the right in the back is R. Stewart McWilliams. He is working with a Raman system.

(Bottom) Diagrams show a schematic of the laser-driven dynamic experiments in a diamond anvil cell. At left is the diamond anvil cell and the laser source. The middle image shows how the initial heating produces a shock wave in about one nanosecond. The right image shows how the heat wave propagates in about one microsecond.

Global Ecology

Linking Ecosystem Processes with Large-scale Impacts

Solving the Carbon Conundrum

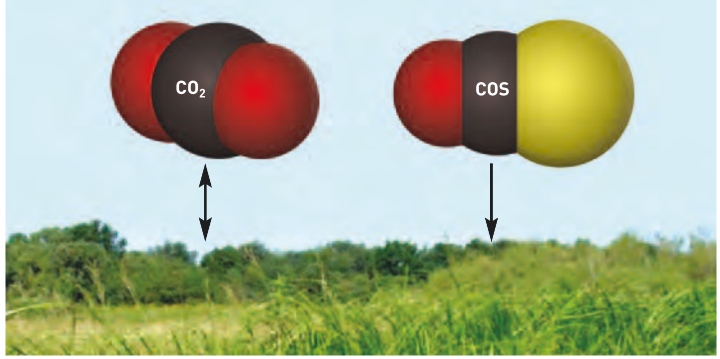
There is a carbon conundrum. Plants take up carbon dioxide (CO_2) in photosynthesis—the conversion of the gas and sunlight into food, water, and oxygen—while it is simultaneously being released as plants respire, or "exhale." So researchers cannot easily tell the net effect. Without accurate measurements, it is not possible to determine how much carbon dioxide comes from different emitters. Joe Berry and colleagues found that they can solve this problem by analyzing the trace gas carbonyl sulfide (COS). They discovered that it is taken up by plants in tandem with CO_2, but it is not emitted by them. The dynamics of this gas uptake, therefore, reflect photosynthesis, not respiration, allowing the two processes to be separated.

Understanding the photosynthesis-climate feedback is key to deciphering how climate change may affect the natural processes that provide a sink for human-made carbon emissions. Carbonyl sulfide is made at the ocean surface by microbes and circulated to the atmosphere at levels roughly a million times lower than CO_2.

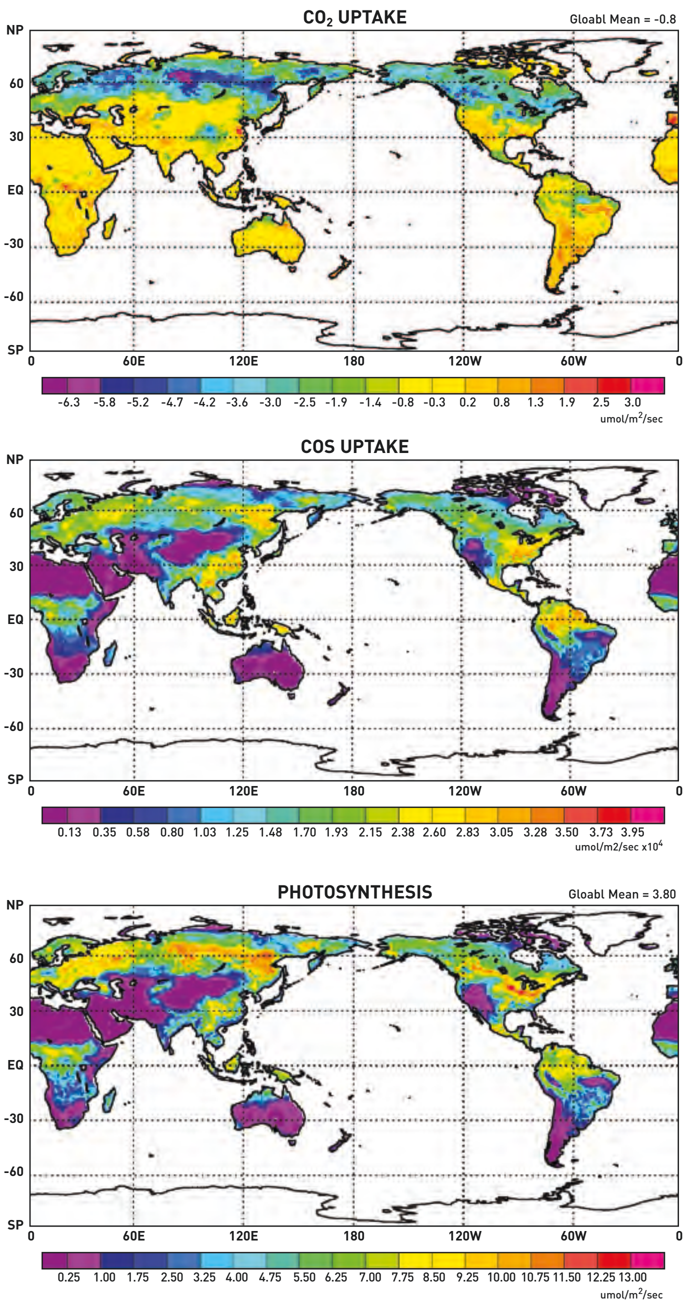
Berry and colleagues from the Weizmann Institute in Israel, U.C. Merced, and Colorado State University have been conducting studies of the kinetics of COS uptake by leaves and have used this information to include COS uptake in a global-scale carbon-cycle model. The team proposes that measurements of COS and net CO_2 uptake, used together, can separate photosynthesis and respiration. To test the hypothesis, the researchers will use an archive of more than 25,000 atmospheric measurements of COS and CO_2 concentration at various locations, collected by researchers at NOAA.

The outcome of this study—that a reverse analysis of the atmospheric carbonyl sulfide measurements may be used to quantify the carbon released during plant respiration—fills the essential piece that has been missing in carbon-cycle research for years.

Carbonyl sulfide (COS) in the atmosphere is taken up by terrestrial ecosystems in parallel with carbon dioxide (CO_2) during photosynthesis. But, unlike CO_2, there is no release of COS associated with respiration, "exhaling." Therefore, changes in the concentration of COS reflect photosynthesis, whereas changes in CO_2 reflect both respiration and photosynthesis.



Global Ecology, *Continued*



(Top) Image shows simulated net CO_2 uptake by the terrestrial biosphere for the month of July. The modeled net CO_2 shows highly productive areas in the tropics (yellow through orange) with near zero net CO_2 exchange similar to deserts. We get this result because we can only see the difference between photosynthesis and respiration. Strong uptake of CO_2 occurs in temperate ecosystems (yellow through orange) because photosynthesis exceeds respiration in this month.

(Center and bottom) Images show that COS uptake has a very similar pattern to photosynthesis. Note that the pattern of COS uptake, which can be measured, is similar to that of photosynthetic uptake of CO_2, which cannot be measured because of interference from respiration. Purple is the lowest level and orange is the highest.

Shifting to Low-Carbon Energy

Global Ecology's Ken Caldeira believes we need to get started on building the next generation of clean energy technologies now if we want to avoid the worst potential effects of climate change caused by greenhouse gases in the atmosphere. Caldeira and Steven Davis, along with former Carnegie postdoc Damon Matthews, asked, what if we never built another CO_2-emitting device, but let the existing technology live out its life span?

They calculated the amount of carbon dioxide expected to be released from existing energy and transportation infrastructure around the world. They used this information to create a model that projects the impact of this infrastructure, if it is unchanged—including power plants, cars, trucks, manufacturing, and waste management—on the Earth's atmosphere going forward to 2060.

Energy infrastructure—such as this power station—as well as cars, trucks, manufacturing, waste management, and other sources of pollution, would release about 500 billion tons of carbon dioxide into the atmosphere between 2010 and 2060.

The photograph was taken by Petr Kratochvil and provided by PublicDomainPictures.net.

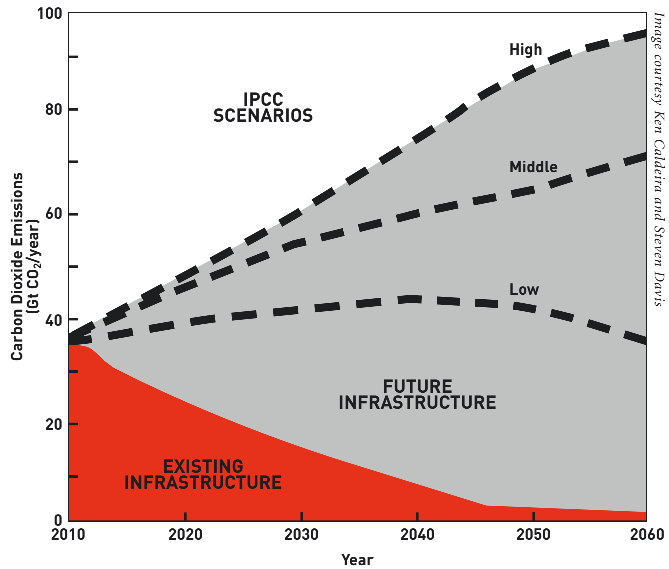


Image courtesy Ken Caldeira and Steven Davis

This graph compares the projected decline of carbon dioxide emissions in gigatons (billions of tons) from existing energy and transportation infrastructure (red wedge) over the next 50 years in three different emissions scenarios (dotted lines) from the Special Report on Emissions Scenarios (SRES) Intergovernmental Panel on Climate Change (IPCC). The high, middle, and low emissions projections correspond to the SRES A1G-FI, A2, and B1 scenarios, respectively.

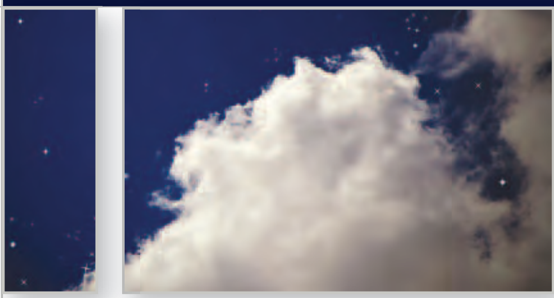
They found that between 2010 and 2060 this infrastructure would release about 500 billion tons of carbon dioxide into the atmosphere. The resulting increase in global mean temperature would be less than 1.3 degrees Celsius (2.34°F). Their work was published in *Science* in September 2010.

If we don't change direction, we will build many more energy and transportation devices in the future. This would lead to an increased impact on Earth's climate. Therefore, to avoid even worse projections for the future of our atmosphere, the research team emphasizes the importance of constructing energy infrastructure and transportation methods that have low carbon emissions now. The greatest risks can be avoided if we start now, according to Caldeira.

The infrastructure overhaul needs to take into account structures that don't directly emit carbon dioxide but do contribute to the inertia of the existing system. For example, the existing network of gas stations around the country makes gasoline-powered vehicles more attractive to consumers than electric vehicles, which have a comparative paucity of recharging infrastructure. □

Observatories

Investigating the Birth, Structure, and Fate of the Universe



Three Cheers for FourStar!

A new, wide-field near-infrared (IR) camera named FourStar saw "first light," in December of 2010, on the Magellan Baade 6.5-meter telescope. Near IR radiation, with wavelengths longer than those of visible light, can be detected from some of the most distant objects in the universe. To see distant galaxies, astronomers often use space-based IR instruments because space is above the moisture, emission, and turbulence of Earth's atmosphere. Now, Eric Persson and his team have designed and built the ground-based FourStar—a highly accurate, unique infrared camera that can see as far back as 2 billion years after the Big Bang. It will address questions about galaxy and cluster evolution for galaxies at intermediate and great distances, and much more. FourStar's unique design is the brainchild of a team of astronomers and engineers. Persson is the principal investigator and Steve Shectman is the architect of the optics, as they were for a prototype IR camera called PANIC. FourStar's field of view is 10.9 x 10.9 arc minutes—about 25 times larger than PANIC's. (For comparison, the Moon's diameter is about 30 arc minutes.) The wavelength range of IR cameras are designated by letters. FourStar covers 1 to 2.5 microns in the *J*, *H*, and *K* bands.

Persson is particularly interested in using FourStar to understand the era from 2 billion to 5 billion years after the Big Bang. During this time, the first galaxies had stopped forming stars, there is ample evidence of galaxy evolution, and galaxy clusters started to form. It is difficult to study the very faint objects of this era using ordinary techniques. So the team split the *J* and *H* bands into subsets—the *J* band into three and the *H* band into two. By increasing the bands from 2 to 5, the researchers obtain more samples, which refines the data for better spectral resolution.

Image courtesy Frank Perez

(Far left) Andy Monson (left), principal investigator Eric Persson (middle), and Randy Hammond (right) stand with the FourStar camera mounted on the Magellan Baade telescope.

(Top right) Eric Persson sits in front of the monitor that shows the first galaxy imaged by FourStar in December 2010.

(Bottom right) The two circles on this image of the sky encompass two galaxy groupings in a probable cluster forming 3 billion years after the Big Bang. The display colors were adjusted to pick out intrinsically redder galaxies using the band-splitting technique that the team developed. The red colors and tendency to appear in tight groupings are the telltale signs of a distant cluster.

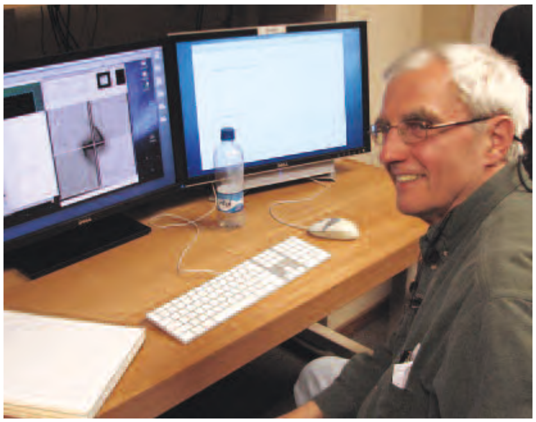


Image courtesy Alan Uomoto

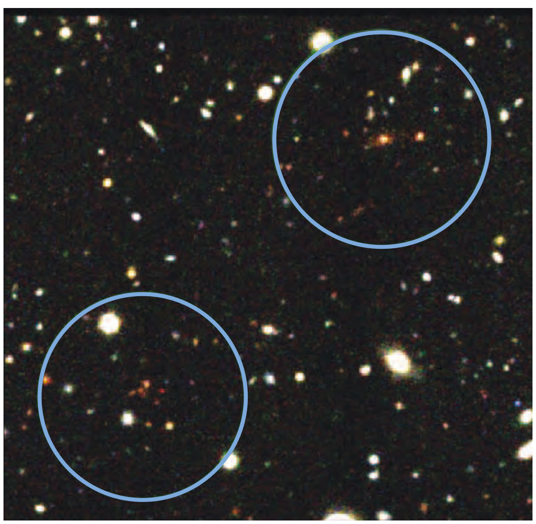


Image courtesy Ivo Labbé

Accurate measurements, obtained over exposures of several hours in each band, are analyzed to yield the distances to very distant galaxies and clusters as well as the type and age of galaxies. Instead of measuring one or a few galaxies at a time, FourStar can measure 10,000 at a time.

Over the next two years the FourStar Galaxy Evolution Survey (Z-FOURGE), a collaboration of astronomers from five institutions led by former postdoctoral associate Ivo Labbé, now at the University of Leiden, with Hubble Fellow Janice Lee and her team, will establish a benchmark of galaxy characteristics by measuring some 30,000 galaxies from that era.

Scrutinizing Supernovae

Certain two-star systems end their lives as gigantic thermonuclear explosions called supernovae, which remain exceedingly bright for some weeks. The extreme brightness of Type Ia supernovae makes them attractive for astronomers to determine distances in the universe, making them so-called standard candles. By measuring a number of these objects over a decade ago, Mark Phillips and the High-z Supernova Search Team discovered that the universe is expanding at an accelerating rate—a fact that is the foundation for the notion of dark energy, which makes up some 70% of the energy density of the universe. Although the brightness of these objects is very similar, there are some differences. Phillips and collabora-

Observatories, *Continued*

Image courtesy Mark Phillips

Image courtesy Mark Phillips

These are composite optical images. The left image shows a supernova above and to the left of the nucleus. The right image was taken a year later when the supernova had faded from sight.

tors are calibrating the differences to ensure there are no distortions to the dark energy measurements in a project that expands on the Carnegie Supernova Project, which sampled some 200 supernovae.

One of the biggest difficulties in observing Type Ia supernovae is correcting for obscuring dust. Near-infrared light is able to penetrate the dust. Using the modern near-infrared instrumentation available at the Las Campanas Observatory, including the new FourStar near-infrared camera that came online in December 2010, Phillips and team are scrutinizing supernovae at a new level of detail.

Previous work showed that Type Ia supernovae come from at least two different populations. Those whose light slowly declines are more likely to occur in spiral and irregular galaxies, whereas faster-declining objects tend to occur in older elliptical and so-called SO galaxies. The team is addressing whether all Type Ia supernovae explode in the same way, how differences in the age and chemical composition of the progenitor stars affect their brightness, and how much of the color differences are intrinsic or due to dust. All of these can affect the luminosity—the underpinning of distance measurements.

The new project will obtain both near-infrared and optical light measurements of 100 to 200 Type Ia supernovae at distances of 0.4 to 1.0 billion light-years—near enough to study the supernovae in detail, but far enough to give an independent estimate of their relative distances. This will allow Phillips and his team to quantify the nature of such effects on the luminosities of Type Ia supernovae, an important next step in understanding the nature of dark energy. □

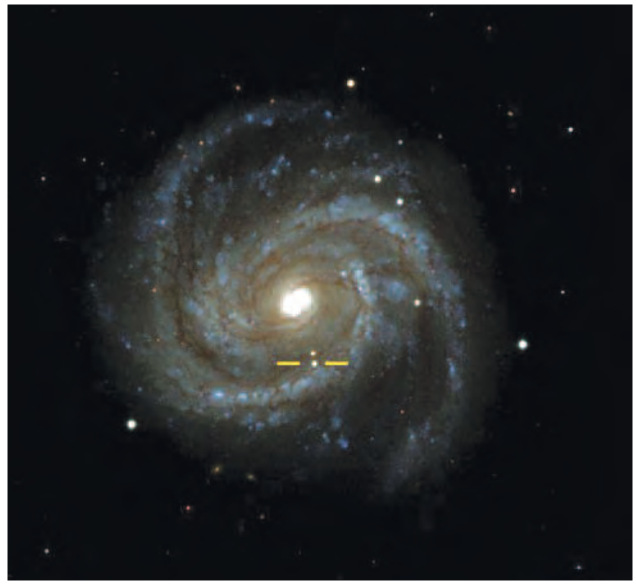


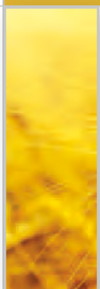
Image courtesy Mark Phillips

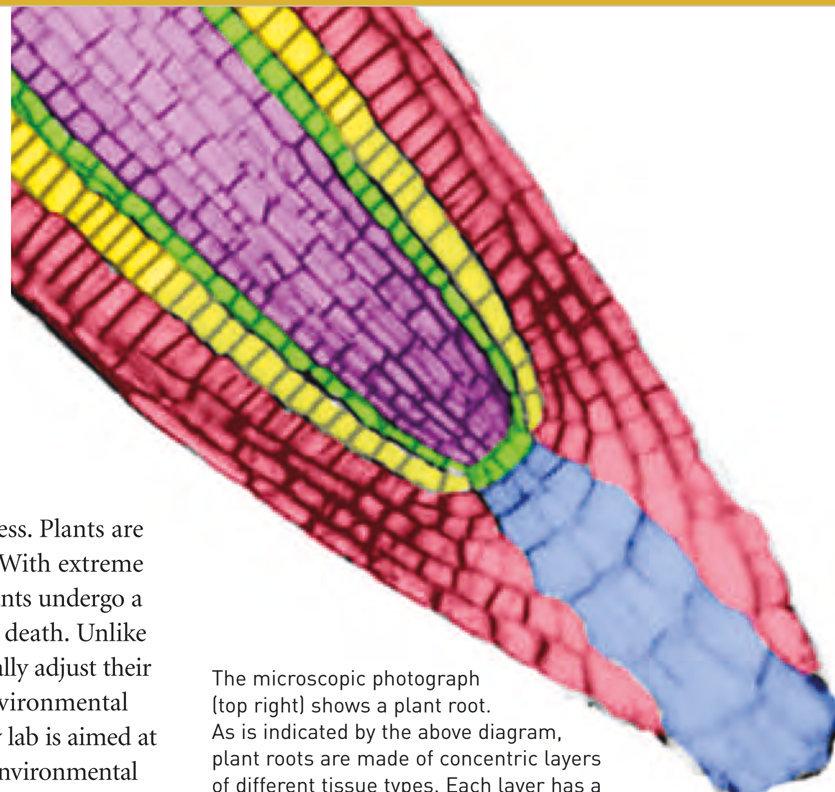
(Top) The yellow bar indicates Supernova 2006X, one of the Type Ia supernova measured in the Carnegie Supernova Project.

(Bottom) Mark Phillips is the associate director of Carnegie's Las Campanas Observatory.

Plant Biology

Characterizing the Genes of Plant Growth and Development





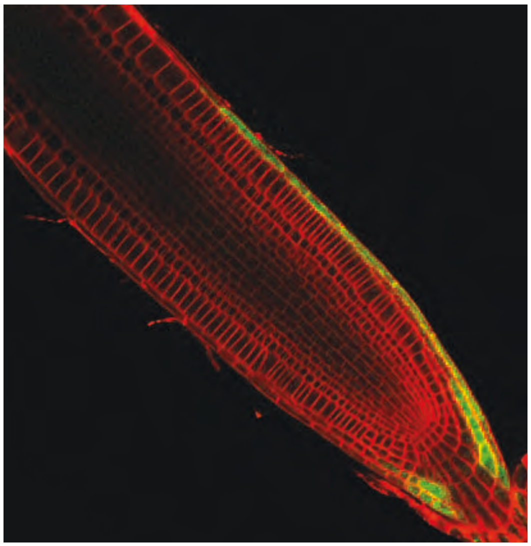
The microscopic photograph (top right) shows a plant root. As is indicated by the above diagram, plant roots are made of concentric layers of different tissue types. Each layer has a different function in absorbing the water and nutrients necessary to support the growth of the aboveground shoot. For example, the endodermis (green) acts as a selective barrier limiting the types of materials that can enter the vasculature system (purple)—the tissues that circulate water. The root tip senses gravity in guiding the root downward.

Stressed-Out Plants

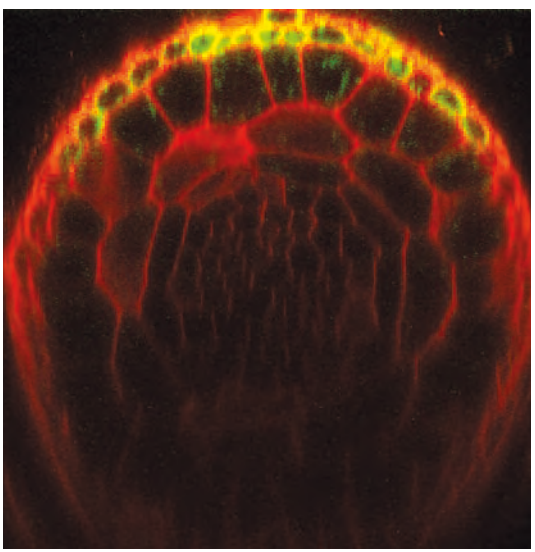
People are not the only ones who suffer stress. Plants are highly sensitive to environmental changes. With extreme changes, such as drought or high salinity, plants undergo a stress response to prevent further injury or death. Unlike animals that can move, plants must continually adjust their growth and development to adapt to an environmental change. Research in the new José R. Dinneny lab is aimed at understanding the developmental basis for environmental responses of the root system—the "hidden half" of plants. Most recently, the researchers have identified a gene involved in sensing water availability, which could be a key step toward engineering plants to withstand drought.

Plant roots are composed of concentric layers of different tissue types. Each layer has a different function in absorbing the water and nutrients necessary to support the growth of the aboveground shoot. During his postdoctoral fellowship at Duke University, Dinneny discovered that each tissue layer plays a distinct role in response to stresses, such as high salinity and iron-nutrient deprivation. One key question the Dinneny lab is currently addressing is how each tissue layer of the root generates unique responses to the same stimulus. They are trying to understand how genes, which control acclimation, are activated differently in different tissues.

A new area of research in the lab is focused on understanding how plants are able to sense the presence of water in the soil. The ability of plants to grow toward soil with higher relative moisture has been known since the time of Darwin, yet the mechanism involved in guiding the root has remained a mystery.



Images courtesy José Dinneny



Images courtesy José Dinneny

The Dinneny lab recently identified a gene, NCED2, involved in the biosynthesis of the stress hormone abscisic acid. This gene has the unique property of being activated in cells of the root directly contacting liquid and suppressed in cells contacting air. Current studies are investigating the role of hormone-signaling gradients in regulating the growth and tissue patterning of the root. This work will lead to an understanding of how cells are able to perceive differences in moisture content and how these pathways differ in plants adapted to arid environments.

Improving Plants, Increasing Food

When photosynthesis first evolved, the atmosphere contained much more carbon dioxide and much less oxygen than it does today. As a result, the photosynthetic machinery of many organisms may not be completely optimized for today's environment. Plant Biology's Martin Jonikas is working to understand, and eventually increase, photosynthetic efficiency.

The protein responsible for fixing carbon dioxide—called Rubisco—worked very well in the Earth's early atmosphere. As photosynthetic organisms spread around the world, they absorbed carbon dioxide and released oxygen at such a rate that atmospheric levels of oxygen rose and levels of carbon dioxide fell dramatically. The decreased carbon dioxide concentrations revealed a critical flaw in Rubisco. Under the

(Top) The green fluorescence tag on this root structure shows where the gene NCED2 has been turned on. The lab discovered that the gene marks which side is drier and thereby indicates the ability of the root to perceive local differences in the environment. More green marks the driest side (top).

(Bottom) This cross section of a root shows where the gene NCED2 has been turned on to indicate the driest side (green at top).

Plant Biology, *Continued*

low concentrations of carbon present in today's atmosphere, Rubisco functions extremely slowly and often costs plants metabolic energy when it mistakenly fixes oxygen instead of carbon dioxide. However, Rubisco is such a central component of the photosynthetic metabolism that it cannot be removed or replaced, in spite of its inefficiency.

In March 2011, Martin Jonikas and three U.K. collaborators received one of four grants from the U.S. National Science Foundation and the U.K. Biotechnology and Biological Sciences Research Council to fund research on increasing photosynthetic efficiency.

Jonikas and his colleagues are studying a special mechanism by which the unicellular green alga *Chlamydomonas* is able to increase the concentration of carbon dioxide in proximity to Rubisco, thus dramatically improving its performance and improving the overall efficiency of photosynthesis.

The growth rate of several major crop plants, including wheat and rice, is often limited by their slowness in assimilating carbon from the atmosphere. If Jonikas and his colleagues can transfer the green algal carbon dioxide–concentrating ability to these crops, then they might improve food production around the world. □

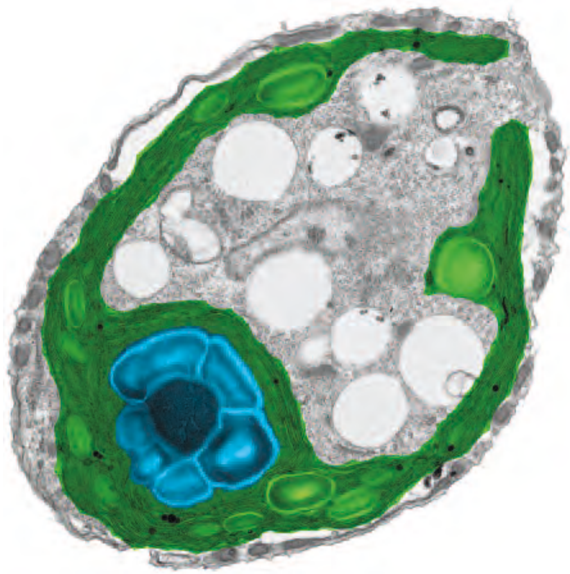


Image courtesy Moritz Meyer

This electron microscopy of the green alga *Chlamydomonas* reveals a ball-shaped structure within the cell, called the pyrenoid (shaded in blue), which helps these algae assimilate carbon to improve their photosynthetic efficiency. The pyrenoid sits in the middle of the chloroplast (shaded in green). Jonikas and his collaborators will characterize the pyrenoid and associated components, and aim to transfer them to higher plants in an effort to improve their photosynthetic efficiency.

Members of the Jonikas lab are (left to right) Weronika Patena, Spencer Gang, Ute Armbruster, Ru Zhang, Mia Terashima, and Martin Jonikas. Not pictured are Leif Pallesen and Sean Blum.

Terrestrial Magnetism

Understanding Earth, Other Planets, and Their Place in the Cosmos

What Sparks Volcanoes?

Understanding the chain of events that lead to volcanic eruptions will help scientists understand volcanic structure and perhaps lead to eruption prediction. For some years, Selwyn Sacks and Alan Linde have been studying volcanic activity. Recently, Diana Roman joined the staff to boost these investigations. She studies relationships among magma flow, seismicity, local stresses, and more.

Linde, Sacks, and colleagues have been studying changes in the Soufrière Hills volcano on the Caribbean island of Montserrat since 2003. The team uses Sacks-Evertson strainmeters, codeveloped by Sacks, to measure tiny levels of deformation within the Earth. The instruments are buried in four 670-foot-deep boreholes 3.3 to 5.7 miles (5.3 to 9.2 kilometers) from the volcanic crater.

In 2003 there was a major dome collapse with subsequent explosions affecting the conduit—the pipe through which magma ascends over the uppermost mile to the surface. Strainmeter data showed that a shallow reservoir (about 3 miles, or 5 kilometers deep) had experienced increased pressure. An explosion in March 2004 required an additional pressure source, associated with gas entering a shallow dike from the magma chamber before breaking out at the surface. Later data also revealed the existence of a deeper (about 7 miles, or 11 kilometers) reservoir. The researchers determined that the upper chamber and dike had been active since 2004, and that a connection between the deep and shallower magma chambers had developed by 2008.

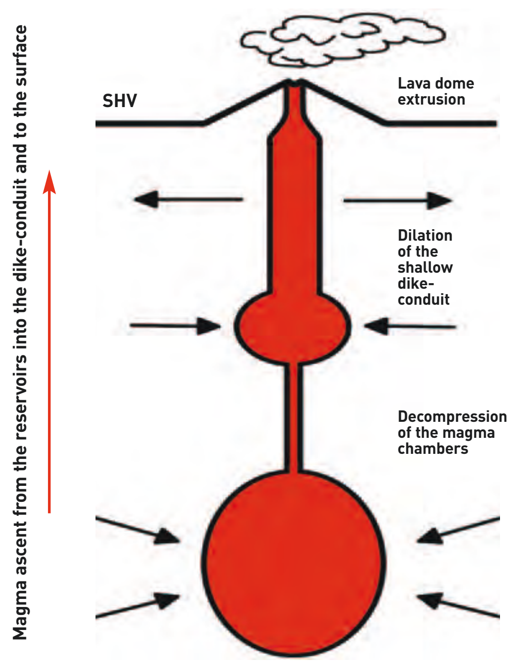


Image courtesy Selwyn Sacks

From seven years of strain data from a suite of instruments, Selwyn Sacks, Alan Linde, and colleagues modeled the structure of magma bodies beneath the Soufrière Hills volcano (SHV) on the Caribbean island of Montserrat. There is one deep and one shallow magma chamber, connected by a conduit. A wider dike conduit atop the shallower magma chamber allows material to flow to the surface. The scientists found that the gas path slowed markedly from 2004 to 2010 and was not controlled by viscous magma.

Terrestrial Magnetism, *Continued*

Image courtesy Diana Roman

Diana Roman deploys a broadband seismometer at Crater Lake volcano, Oregon, in June 2008.

Diana Roman also seeks to understand volcanic systems by analyzing minute amounts of deformation deep in the Earth. By examining the pattern of rock breakage encoded in microearthquakes beneath restless volcanoes, she looks for pressurizing batches of magma weeks to months before they reach the surface. Currently, she and her team are analyzing data from approximately a dozen active volcanoes in the United States, Nicaragua, New Zealand, and Iceland.

What Makes the High Lava Plains So Hot?

Volcanoes tend to concentrate along the boundaries of tectonic plates and in oceanic regions with particularly high rates of volcanic outflows, or "hotspots," such as Hawaii. But in some instances notable volcanic activity occurs within a stable continental plate. Scientists have

Image courtesy John West, Arizona State University

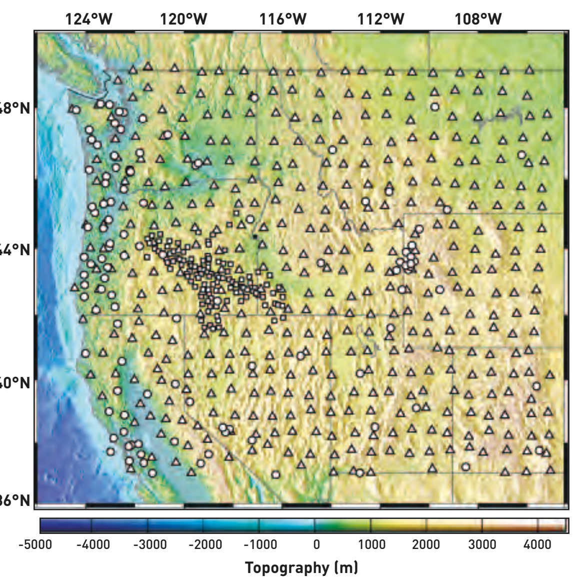


Image courtesy Matt Fouch and David James

(Top right) Matt Fouch (standing on right), Steven Golden (DTM's field seismologist, kneeling), and David James (with vest), along with Arizona State University students Shaji Nair (left) and Jeff Roth, confer in a strategy session in the midst of a station installation on the High Lava Plains of eastern Oregon.

(Bottom right) This shaded topographic map of the northwestern U.S. shows locations of broadband seismic stations used for this study. Small squares indicate High Lava Plains stations, white triangles denote EarthScope Transportable Array stations, and circles denote other regional broadband stations.

been puzzled by the processes governing this "intraplate" volcanism. Rarely, these intraplate volcanoes involve huge outpourings of lava to form rocks called flood basalts, which are commonly attributed to a plume of magma upwelling from the deep mantle. It is thus not surprising that geologists have favored a mantle-plume model to explain the great volumes of flood basalts and later volcanic eruptions that have blanketed the U.S. Pacific Northwest east of the Cascades over the past 17 million years. New research from the multidisciplinary High Lava Plains (HLP) Project led by DTM scientists, however, suggests an alternative interpretation based on a complex history of the oceanic Juan de Fuca plate as it "subducted," or descended beneath, the Pacific margin of the North American plate.

The research area includes the High Lava Plains of central and eastern Oregon and the Snake River Plain/Yellowstone region. The HLP seismological team, led by coprincipal investigators David James and newly arrived staff member Matthew Fouch, with a team of colleagues and students from the department and other institutions, deployed broadband seismic instruments at 118 stations in the region over three years in one of the largest seismic experiments ever of its kind. Rick Carlson leads the overall multidisciplinary effort.

With the HLP data, augmented by data from EarthScope USArray stations, the team obtained high-resolution seis-

Terrestrial Magnetism, *Continued*

mic images of the mantle beneath the region. Surprisingly, these images do not show a deep mantle plume, but reveal that the Juan de Fuca slab has been extensively broken or fragmented, with a far-eastward fragment of oceanic slab adrift in the mantle 250 to 370 miles (400 to 600 kilometers) under the Snake River Plain/Yellowstone hotspot. These structures suggest that slab-generated magma upwelling could produce the plumelike hotspot without involving a deep mantle plume.

The team also took a closer look at the Steens Mountain and Columbia River flood basalts, which erupted 17 million years ago, and suggest that these eruptions may have been caused by slab disruption about 20 million years ago with a subsequent reinitiation of a new subduction cycle when the Juan de Fuca plate began anew its descent beneath North America. □

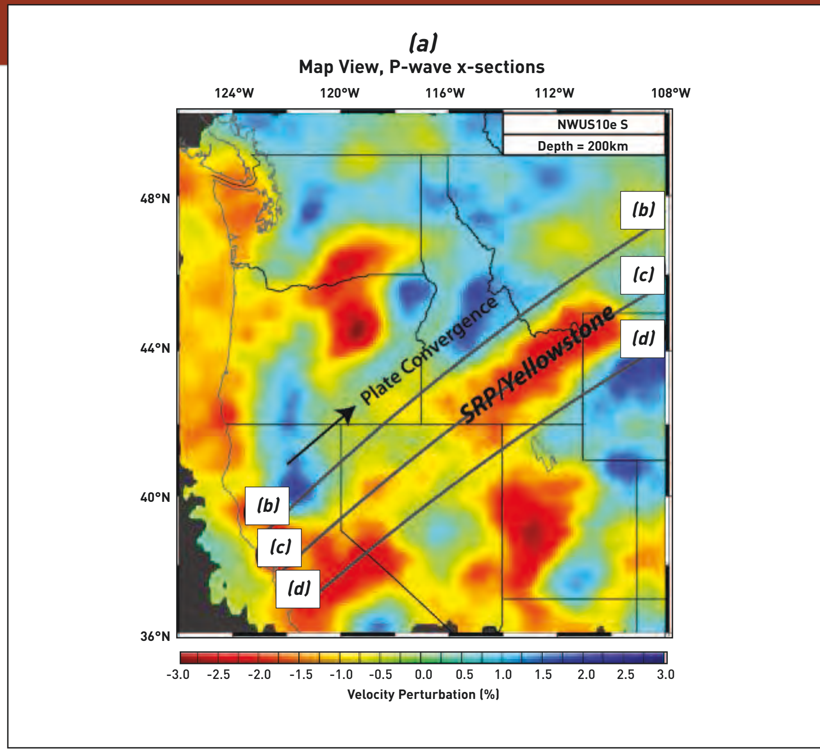


Image courtesy David James and Matt Fouch

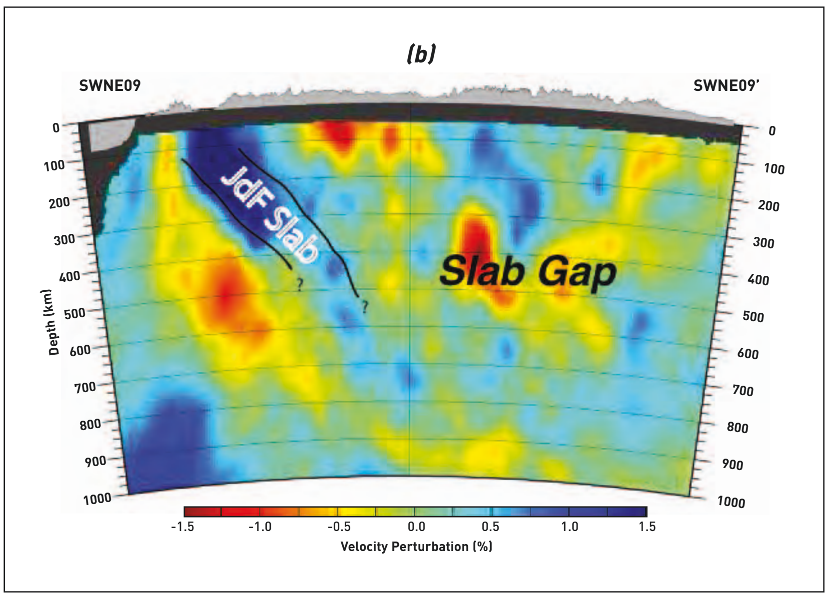


Image courtesy David James and Matt Fouch

Image courtesy David James and Matt Fouch

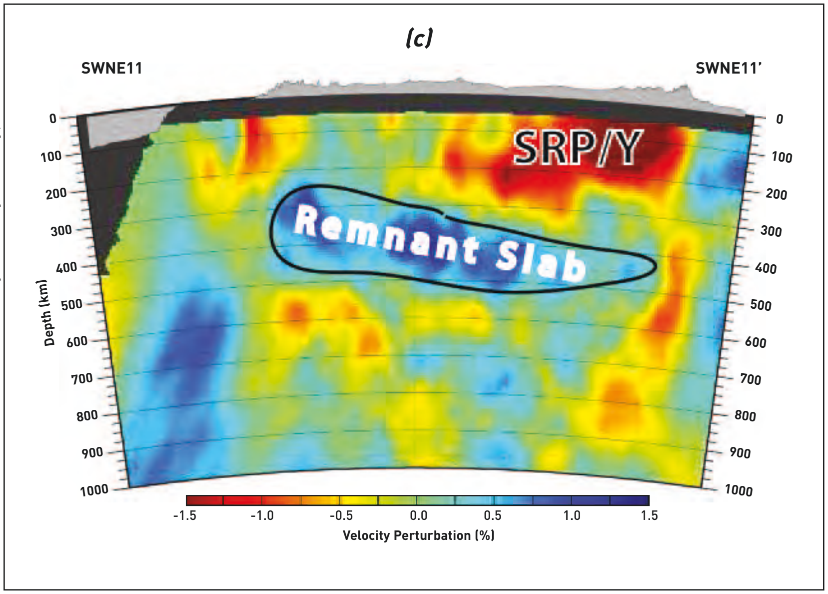
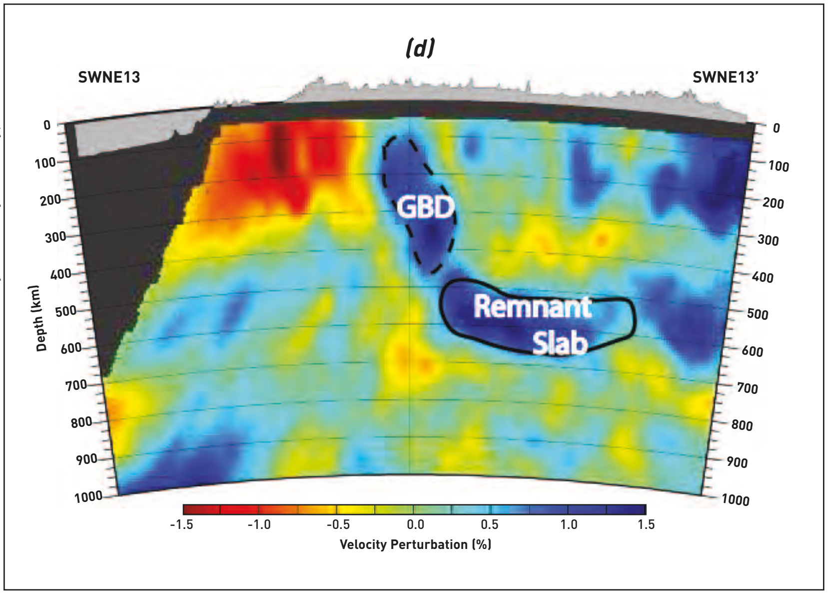


Image courtesy David James and Matt Fouch



This series of cross sections of tomographic seismic images begins with a top-down view of the study area at about 125 miles (200 kilometers) in depth (panel a). This map view provides a key to the surface traces of the vertical cross sections shown in the other three images (b, c, and d), which are aligned with the direction of convergence of the North American and Juan de Fuca plates. Red areas in all of these images indicate low seismic velocities indicative of high temperatures, and blue indicates higher velocities and lower temperatures. Image (b) shows the normal descent (subduction) of the cold Juan de Fuca (JdF) slab, with a slab gap to the east. The key image is that shown in panel (c), a vertical cross section oriented directly along the axis of the Snake River Plain/Yellowstone hotspot track. Panel (c) reveals a very gently northeast-dipping (subhorizontal) remnant of a slab of the now-subducted Farallon plate adrift in the mantle transition zone. Its leading edge is just beneath Yellowstone. Panel (d) shows the southern continuation of the remnant slab as well as part of the Great Basin Drip (labeled GBD) —a column of cold lithospheric material descending into the mantle like dripping honey.

First Light & The Carnegie Academy

Teaching the Art of Teaching Science and Math

From Local Teachers to Other Planets

It was a big year for the MESSENGER Mission to Mercury, and likewise it was a big year for the MESSENGER Education and Public Outreach team. Their hallmark program, MESSENGER Education Fellows, had six participants attend the probe's orbit insertion event in March and five attend the mission's Science Team meeting in May. The program provides educational materials and background for educators to lead workshops back in their communities to help local teachers improve their curriculum about space in general and the mission itself. The team leader, Carnegie's Julie Edmonds, estimates that by the end of the MESSENGER mission, the program will have trained 20,000 teachers and reached over a million students.

The team also conducted a multisite workshop for 140 educators in May, allowing teachers to get face-to-face time with scientists, including Carnegie's Sean Solomon, who is MESSENGER's principal investigator, at four different locations as well as via NASA's Digital Learning Network. Public events included a table of MESSENGER scientists at the annual meeting of AAAS, which reached approximately 600 people, and an entire event devoted to MESSENGER at the Hands-On science museum in Ann Arbor, Michigan, where children were able to participate in activities that taught them about Mercury and about the mission.

It All Adds Up

The Math for America (MfA) DC Fellowship Program, initiated by Carnegie, already has three cohorts and is recruiting another. The fellows spend 15 months getting a master's degree in math education at MfA's expense—coursework includes math pedagogy and graduate-level mathematics—in return for four years teaching math at District of Columbia public and public charter secondary schools. There are currently six fellows in the master's program. The group of 14 current teaching fellows are reaching around 1,100 students in the District of Columbia.

The program is one of seven nationwide. Each works with one or more academic partners, including American University for the Washington-based program. The program recruits recent graduates and career changers with strong math, physics, or engineering backgrounds who are interested in teaching. It focuses on high-need schools, predominately in urban areas. The goal is to use the participant's math skills as a lens to focus on secondary school students who are behind the learning curve, and bring them up to speed quickly and efficiently.

During the required four years of teaching, the fellows meet once a month for professional development programs, receive continual one-on-one mentoring, and attend occasional social events. □

for Science Education

MESSENGER Principal Investigator Sean Solomon talks to children about the mission during an event at the Ann Arbor Hands-On Museum August 16, 2011. The event was hosted by the museum with participation by the MESSENGER Education and Public Outreach team and several members of the MESSENGER science and engineering teams.

CASE's Guy Brandenburg (in profile) leads third-cohort fellows in the popular Math on the Mall development program, which included real-world spatial math projects on the National Mall in June 2011. Left to right are Lawrence Chien, Rebecca Dunn, Ariel Kramer, Conor Kenney (obstructed), Joe Herbert, and Jessica Ogle.

Shown here are MESSENGER Educator Fellows and members of the Education and Public Outreach and science teams at the orbit insertion event March 17, 2011. Left to right: Robert Farquha (science team), Cathy Williamson (fellow), Christina Dorr (fellow), Lollie Garay (fellow), Julie Edmonds (E&PO team), Susie Miller (fellow), Carol Fraser (fellow), Heather Weir (E&PO team), Robert Petro (fellow), Sean Solomon (science team), and Harri Vanhala (E&PO team).

Participants at the Hands-On Museum event, shown right, use the Education and Public Outreach team's MESSENGER Mosaic Postcards to learn about the mission and the planet.

Financial Profile

for the year ending June 30, 2011 (unaudited)

Reader's Note: *In this section, we present summary financial information that is unaudited. Each year the Carnegie Institution, through the Audit committee of its Board of Trustees, engages an independent auditor to express an opinion about the financial statements and the financial position of the institution. The complete audited financial statements are made available on the institution's website at www.carnegieScience.edu.*

The Carnegie Institution of Washington completed fiscal year 2011 in sound financial condition due to the positive returns (+22.7%) of the diversified investments within its endowment; a disciplined spending policy that balances today's needs with the long-term requirements of the institution and the interests of future scientists; and the continued support of organizations and individuals who recognize the value of nurturing basic science.

The single primary source of support for the institution's activities continues to be its endowment. This reliance on institutional funding provides an important degree of independence in the research activities of the institution's scientists.

As of June 30, 2011, the endowment was valued at $796 million. Over the period 2001-2011, average annual increases in endowment contributions to the budget were 5.5%. In this era of continuing market volatility, Carnegie closely controls expenses in order to ensure the continuation of a healthy scientific enterprise.

For a number of years, under the direction of the Finance committee of the board, Carnegie's endowment has been allocated among a broad spectrum of asset classes including: fixed-income instruments (bonds), equities (stocks), absolute return investments, real estate partnerships, private equity, and natural resources partnerships. The goal of this diversified approach is to generate attractive overall performance and minimize the volatility that would exist in a less diversified portfolio.

The Finance committee of the board regularly examines the asset allocation of the endowment and readjusts the allocation, as appropriate. The institution relies upon external managers and partnerships to conduct the investment activities, and it employs a commercial bank to maintain custody. The following chart shows the allocation of the institution's endowment among asset classes as of June 30, 2011.

Asset Class	Target	Actual
Common Stock	37.5%	39.0%
Alternative Assets	55.0%	54.0%
Fixed Income and Cash	7.5%	7.0%

Carnegie's investment goals are to provide high levels of current support to the institution and to maintain the long-term spending power of its endowment. The success of Carnegie's investment strategy is illustrated in the first figure that compares, for a hypothetical investment of $100 million, Carnegie's investment returns with the average returns for all educational institutions for the last twelve years.

Carnegie has pursued a long-term policy of controlling its spending rate, bringing the budgeted rate down in a gradual fashion from 6+ % in 1992 to 5.00% today. Carnegie employs what is known as a 70/30 hybrid spending rule. That is, the amounts available from the endowment in any year is made up of 70% of the previous year's budget, adjusted for inflation, and 30% of the most recently completed year-end endowment value, multiplied by the spending rate of 5.0% and adjusted for inflation and for debt. This method reduces volatility from year-to-year. The second figure depicts actual spending as a percentage of ending market value for the last 20 years.

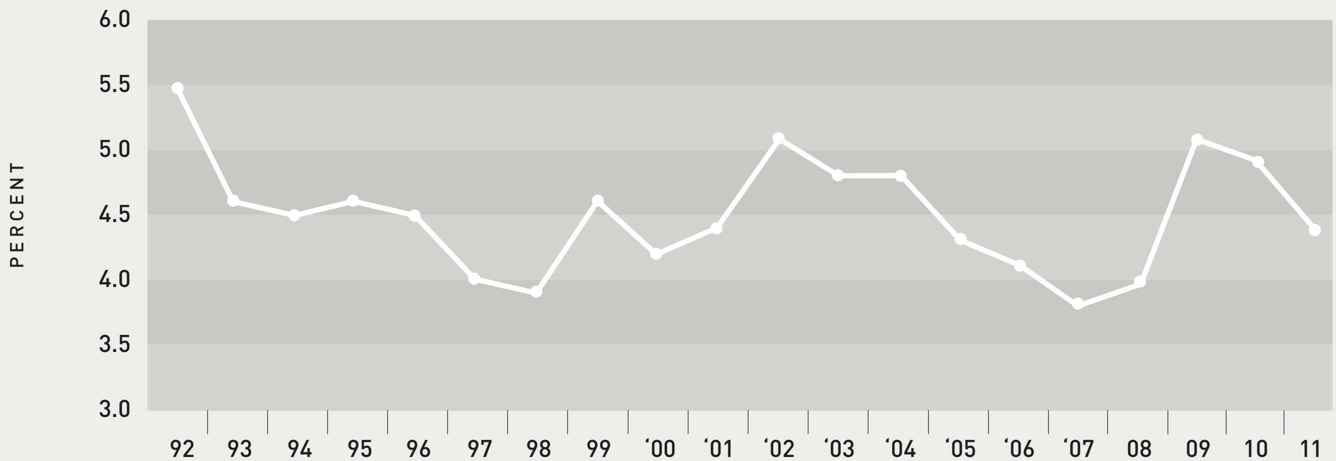
In fiscal year 2011, Carnegie benefitted from continuing federal support. Carnegie's federal support has grown from $24.5 million in 2006 to more than $34 million in new grants in 2011. This is a testament to the high quality of Carnegie scientists and their ability to compete successfully for federal funds in this period of fiscal restraint.

Carnegie also benefits from generous support from foundations and individuals. Funding from foundations has grown from an average of about $3 million/year in the period from 2000 to 2004 to a record $9 million in 2011. Within Carnegie's endowment, there are a number of "funds" that provide support either in a general way or targeted to a specific purpose. The largest of these is the Andrew Carnegie Fund, begun with the original gift of $10 million. Mr. Carnegie later made additional gifts totaling another $12 million during his lifetime. This tradition of generous support for Carnegie's scientific mission has continued throughout our history, and a list of donors in fiscal year 2011 appears in an earlier section of this year book. In addition, Carnegie receives important federal and private grants for specific research purposes, including support from the Howard Hughes Medical Institute for researchers at the Department of Embryology.

Illustration of $100 Million Investment - Carnegie Returns vs. Average Returns for All Educational Institutions (2000-2011)

Average returns for educational institutions are taken from Commonfund reports on endowment performance.

Endowment Spending as a Percent of Ending Endowment Value*



*Includes debt financing.

Statements of Financial Position (unaudited)

June 30, 2011, and 2010

	2011	2010
Assets		
Current assets:		
Cash and cash equivalents	$ 1,518,067	$ 32,359,327
Accrued investment income	0	46,301
Contributions receivable	7,298,027	6,342,270
Accounts receivable and other assets	17,279,764	20,411,836
Bond proceeds held by Trustee	17,694	26,728
Total current assets	$ 26,113,552	$ 59,186,462
Noncurrent assets:		
Investments	795,672,507	688,251,697
Property and equipment, net	154,768,137	156,738,554
Total noncurrent assets	$950,440,644	$844,990,251
Total assets	$976,554,196	$904,176,713
Liabilities and Net Assets		
Accounts payable and accrued expenses	$ 10,918,845	$ 18,579,451
Amount held for others	0	33,186,239
Deferred revenues	31,307,772	33,916,916
Bonds payable	65,728,416	65,800,315
Accrued postretirement benefits	17,206,079	15,246,053
Total liabilities	$125,161,112	$166,728,974
Net assets		
Unrestricted	$244,949,855	$217,326,563
Temporarily restricted	551,513,903	465,231,580
Permanently restricted	54,929,326	54,889,596
Total net assets	$851,393,084	$737,447,739
Total liabilities and net assets	$976,554,196	$904,176,713

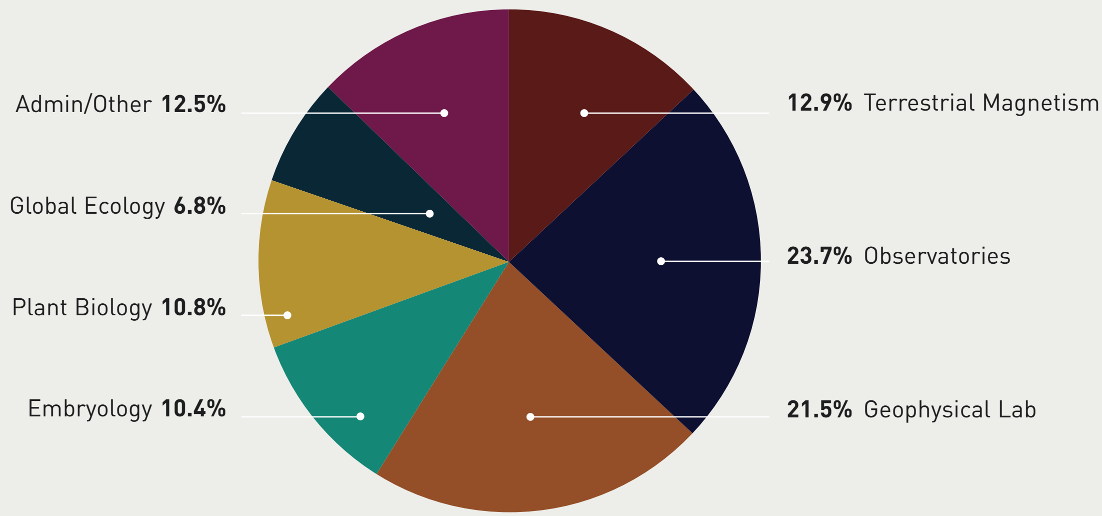
Statements of Activities[1] (unaudited)

Periods ended June 30, 2011 and 2010

	2011	2010
Revenue and support:		
Grants and contracts	$ 40,480,694	$ 42,707,752
Contributions, gifts	13,081,598	14,255,572
Other income	18,583	898,225
Net external revenue	$ 53,580,875	$ 57,861,549
Investment income and unrealized gains (losses)	$153,142,080	$ 85,323,573
Total revenues, gains, other support	$206,722,955	$143,185,122
Program and supporting services:		
Terrestrial Magnetism	$ 11,957,202	$ 11,210,212
Observatories	21,920,605	26,961,521
Geophysical Laboratory	19,962,665	16,464,866
Embryology	9,670,782	8,959,492
Plant Biology	10,032,715	10,284,361
Global Ecology	6,267,032	7,378,555
Other programs	1,050,387	915,319
Administration and general expenses	10,556,630	10,495,497
Total expenses	$ 41,418,018	$ 92,669,823
Change in net assets before pension related changes	$115,304,937	$ 50,515,299
Pension Related Changes	(1,359,592)	(53,052)
Net assets at the beginning of the period	$737,447,739	$686,985,492
Net assets at the end of the period	$851,393,084	$737,447,739

[1] Includes restricted, temporarily restricted, and permanently restricted revenues, gains, and other support.

2011 Expenses by Department ($91.4 Million)



Personnel

July 1, 2010-June 30, 2011

Carnegie Administration

Benjamin Barbin, *Manager of Advancement Activities*
Shaun Beavan, *Systems Administrator*
Gloria Brienza, *Budget and Management Analyst Manager*
Donald Brooks, *Building Maintenance Specialist*
Marjorie Burger, *Financial Manager*
Cady Canapp, *Manager of Human Resources and Insurance*
Alan Cutler, *Science Writer*[1]
Robert Ellis, *Web Developer*
Kristen Fisher, *Special Events and Facility Coordinator*[2]
Alexis Fleming, *Special Events and Facility Coordinator*
Shawn Frazier, *Accounting Assistant*
Dina Freydin, *Senior Grants Accountant*
Susanne, Garvey, *Director of External Affairs*
Darla, Keefer, *Special Assistant for Administration and Building Operations*
Mulyono Kertajaya, *Business Data Analyst*
Ann Keyes, *Payroll Coordinator*
Yang Kim, *Deputy Financial Manager*
Lisa Klow, *Executive Assistant to the President*[3]
G. Gary Kowalczyk, *Director of Administration and Finance*
Tina, McDowell, *Editor and Publications Officer*
Richard A. Meserve, *President*
Natasha Metzler, *Science Writer*[4]
Christina Naguiat, *Executive Assistant to the President*[5]
June Napoco-Soriente, *Financial Accountant*
Mikhail Pimenov, *Endowment Manager*
Gotthard Sághi-Szabó, *Chief Information Officer*
C. Rick Sherman, *Chief Advancement Officer*[6]
Harminder Singh, *Financial Accountant*
John Strom, *Multimedia Designer/Producer*
Mira, Thompson, *Manager of Advancement Operations*[7]
Laura Unterholzner, *Special Events/Building Assistant*[8]
Yulonda R. White, *Human Resources and Records Coordinator*
Jacqueline Williams, *Assistant to Human Resources and Insurance Manager*

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[1]To August 20, 2010
[2]To December 3, 2010
[3]To January 31, 2011
[4]From November 8, 2010
[5]From January 20, 2011
[6] From February 21, 2011
[7]To May 13, 2011
[8]From December 7, 2010

Carnegie Academy for Science Education

Bianca Abrams, *Director, Math for America (MfA)*
Brianna Anderson, *STARS Program Intern*[2]
Joel Battle, *First Light Volunteer*
Sarah Bax, *CASE Mentor*[1]
Guy Brandenburg, *First Light Instructor, CASE and MfA Mentor*
Anne Brooks-Hemphill, *CASE Mentor*[1]
Khalid Bullock, *STARS Program Intern*[1]
Laurence Chien, *Math for America Fellow*
Katherine Collins, *Math for America Fellow*
Kenney Conor, *Math for America Fellow*
Amy Danks, *Math for America Fellow*
Asonja Dorsey, *CASE Mentor*[1]
Lauren Dorsey, *CASE Intern*[1]
Stephen Dorsey, *CASE Intern*[1]
Juwanna Douglas, *STARS Program Intern*[1]
VanNessa Duckett, *CASE Mentor*[1]
Rebecca Dunn, *Math for America Fellow*
Julie Edmonds, *Codirector, CASE*
Anne Farrell, *Math for America Fellow*
Maya Garcia, *CASE Mentor*[1]
Ricky Garibay, *Intern and First Light Assistant*[1]
Darcy Hampton, *CASE Mentor*[1]
Tashima Hawkins, *CASE Mentor*[1]
Joseph Herbert, *Math for America Fellow*
Krystn Hodge, *Math for America Fellow*
Courtney Holmes, *STARS Program Intern*[1]
Alexandra Horenstein, *CASE Fellow*[2]
Toby Horn, *Codirector, CASE*
Dasia Jacob, *STARS Program Intern*[2]
Linda Jamison, *STARS Program Intern*[1]
Marlena Jones, *CASE Coordinator*
Molley Kaiyoorowongs, *Math for America Fellow*
Brian Kim, *Research Assistant*[1]
Sarah Kennedy, *CASE Intern*[2]
Ariel Kramer, *Math for America Fellow*
Sophia Lallinger, *Math for America Fellow*
Shameka Lyles, *STARS Program Intern*[1]
Lindsay Mann, *Math for America Fellow*
Emily Marks, *Administrative Assistant, MfA*[3]
Mirielle Mbepeh, *STARS Program Intern*[2]
Dakari McAdoo, *First Light Volunteer*
Jeanah McCall, *CASE Intern*[1]
Max Mikulec, *Math for America Fellow*
Devonte Miles, *STARS Program Intern*[1]
Thomas Nassif, *CASE Mentor*[1]
Jessica Ogle, *Math for America Fellow*
Maximilian Olivier, *Math for America Fellow*
Julia Penn, *Math for America Fellow*
Jessica Reynolds, *Math for America Fellow*
Debron Rodney, *CASE Intern*[1]
John Solano, *CASE Fellow*[1]
Lauren Soriente, *CASE Volunteer*
Grier Starling, *STARS Program Intern*[2]
Dashawn Taylor, *STARS Program Intern*[1]
Jasmine Thomas, *STARS Program Intern*[1]
Tierra Thornton, *STARS Program Intern*[1]
Samuel Trichtinger, *Math for America Fellow*
Meredith Wachs, *Math for America Fellow*
Christina Warner, *Administrative Assistant, MfA*[4]
Brittany Warren, *STARS Program Intern*[1]
Maya Washington, *STARS Program Intern*[2]
DeVaughn Wilson, *STARS Program Intern*[1]
Heather Zelinsky, *Math for America Fellow*

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[1]Summer 2010
[2]Summer 2011
[3]From February 7, 2011, to May 31, 2011
[4]From August 30, 2010, to January 28, 2011

Embryology

Research Staff Members

Alexsky Bortvin
Donald D. Brown, *Director Emeritus*
Chen-Ming Fan
Steven Farber
Joseph G. Gall
Marnie Halpern
Nicholas T. Ingolia[1]
Allan C. Spradling, *Director*
Yixian Zheng

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David MacPherson

Postdoctoral Fellows and Associates

Sang Jung Ahn, *Research Associate, NIH Grant (Halpern)*
Joshua Bembenek, *Research Associate, Howard Hughes Medical Institute (Zheng)*[2]
Haiyang Chen, *Research Associate, NIH Grant (Zheng)*[3]
Sung Gook Cho, *Research Associate, NIH Grant (MacPherson)*[4]
Tagide deCarvalho, *Research Associate, NIH Grant (Halpern)*
Svetlana Deryusheva, *Visiting Scientist, Carnegie*
Lucilla Facchin, *Carnegie Fellow*
Caroline Flournoy, *Research Associate, NIH Grant (Fan)*[5]
Donald Fox, *Research Associate, Howard Hughes Medical Institute (Spradling)*[6]
Rebecca Frederick, *Research Fellow, American Cancer Society Fellowship*
Megha Ghildiyal, *Research Associate, Howard Hughes Medical Institute (Spradling)*[7]
Mary Goll, *Research Associate, NIH Grant (Halpern)*[8]
Ben Goodman, *Carnegie Fellow*[9]
Daniel Gorelick, *Research Associate, (NRSA Postdoctoral Fellowship)*
Axel Horn, *Research Associate, NIH Grant (Han)*[10]
Mario Izaguirre-Sierra, *Carnegie Fellow*
Shreyas Jadhav, *Carnegie Fellow*[11]
Junling Jia, *Research Associate, Howard Hughes Medical Institute (Zheng)*
Youngjo Kim, *Research Associate, Howard Hughes Medical Institute (Zheng)*
Ming-Chia Lee, *Research Associate, Howard Hughes Medical Institute (Spradling)*
Lei Lei, *Research Associate, Howard Hughes Medical Institute (Spradling)*
Christoph Lepper, *Research Associate, NIH Grant (Fan)*[12]
Robert Levis, *Special Investigator, NIH Grant (Spradling with Baylor College of Medicine, subcontract)*
Zhonghua Liu, *Research Associate, Howard Hughes Medical Institute (Zheng)*
Vicki Losick, *Research Fellow, Jane Coffin Childs Fellowship*
Siew Hui Low, *Research Associate, NIH Grant (Fan)*[13]
Safia Malki, *Research Fellow, McClintock Fellowship*
One Mapp, *Research Associate, Mathers Grant (Farber)*[14]
Irena Martirosyan, *Research Associate, NIH Grant (Han)*[15]
Lucy Morris, *Research Associate, Howard Hughes Medical Institute (Spradling)*
Itay Onn, *Research Associate, Howard Hughes Medical Institute (Spradling)*[16]
Jianjun Sun, *Research Associate, Howard Hughes Medical Institute (Spradling)*
James Walters, *Research Fellow, (NRSA Postdoctoral Fellowship)*
Shusheng Wang, *Research Associate, NIH Grant (Zheng)*
Zheng-an Wu, *Special Investigator, NIH Grant (Gall) and Carnegie Fellow*
Helan Xiao, *Carnegie Fellow*[17]
Erin Zeituni, *Carnegie Collaborative Fellow*[18]
Xiaobin Zheng, *Research Associate, NIH Grant (Zheng)*[19]

Predoctoral Fellows and Associates

Courtney Akitake, *The Johns Hopkins University*[20]
Dean Calahan, *The Johns Hopkins University*[21]
Juliana Carten, *The Johns Hopkins University*
Julio Castaneda, *The Johns Hopkins University*
Valeriya Gaysinskaya, *The Johns Hopkins University*
Pavol Genzor, *The Johns Hopkins University*
Ben Goodman, *The Johns Hopkins University*[22]
Michael Harris, *The Johns Hopkins University*[23]
Margaret Hoang, *The Johns Hopkins University*[24]
Christoph Lepper, *The Johns Hopkins University*[25]
Lydia Li, *The Johns Hopkins University*
Peter Lopez, *The Johns Hopkins University*
Alexis Marianes, *The Johns Hopkins University*
Vanessa Matos-Cruz, *The Johns Hopkins University*
Katie McDole, *The Johns Hopkins University*
Anna McGeachy, *The Johns Hopkins University*[26]
Eric Mills, *The Johns Hopkins University*[27]
Katherine Mitchell, *The Johns Hopkins University*[28]
Rosa Miyares, *The Johns Hopkins University, (NRSA Predoctoral Fellowship and Hollaender Fellowship)*
Tim Mulligan, *The Johns Hopkins University*[29]
Zehra Nizami, *The Johns Hopkins University*
Michelle Rozo, *The Johns Hopkins University*
Andrew Skora, *The Johns Hopkins University*[30]
Abhignya Subedi, *The Johns Hopkins University*
Aaron Welch, *The Johns Hopkins University*[31]
William Yarosh, *The Johns Hopkins University*

Supporting Staff

Arash Adeli, *Animal Technician*
Jen Anderson, *Research Technician*
Susan Artes, *Carnegie Science Outreach Coordinator*
Jordon Boston, *Intern*[32]
Keisha Breland, *Animal Technician*
Molly Broache, *Research Undergraduate*[33]
Valerie Butler, *Carnegie Science Outreach Coordinator*
Bianca Cabri, *Research Undergraduate*[34]
Ellen Cammon, *Howard Hughes Medical Institute Research Technician I*[35]
Patricia Cammon, *Howard Hughes Medical Institute Laboratory Helper*
Eric Chen, *Research Undergraduate*[36]
Dolly Chin, *Administrative Assistant*
Karina Conkrite, *Research Technician*
Min Cui, *Research Specialist*[37]
Carol Davenport, *Howard Hughes Medical Institute Research Technician III*
Eugenia Dikovskaia, *Animal Facility Manager*
Chun Dong, *Research Scientist*
Andrew Eifert, *Assistant Facility Manager*
Daniel Escobar, *Research Technician*[38]
Caroline Haislip, *Student Assistant*[39]
Roger Henry, *Student Assistant*
Amy Herbert, *Student Volunteer*
Alice Hung, *Summer Student*[40]
Ella Jackson, *Howard Hughes Medical Institute Laboratory Helper*
Fred Jackson, *P/T Animal Care Technician*
Connie Jewell, *Microcomputer Support Specialist*
Glenese Johnson, *Laboratory Helper*
Rejeanne Juste, *Research Technician*
Susan Kern, *Business Manager*
Gennadiy Klimachev, *Animal Technician*
Lindsey Knapp, *Student Volunteer*[41]
Amy Kowalski, *Research Technician*
Bill Kupiec, *Information Systems Manager*
Megan Kutzer, *Research Technician*[42]
Warner Lai, *Student Assistant, Ingenuity*[43]
Michelle Macurak, *Research Technician*
Ona Martin, *Howard Hughes Medical Institute Research Technician III*
Tom McDonaugh, *Facilities Manager*
Neda Muzaffar, *Research Technician*[44]
Pedram Nozari, *Animal Technician*
Allison Pinder, *Howard Hughes Medical Institute Research Technician III*
Earl Potts, *Animal Technician*
Christine Pratt, *Howard Hughes Medical Institute Administrative Assistant II*

Joan Pulupa, *Howard Hughes Medical Institute Laboratory Assistant*
Megan Reid, *Laboratory Assistant*
Samantha Satchell, *Research Technician*
Michael Sepanski, *Electron Microscopy Technician*
Mahmud Siddiqi, *Microscope Specialist*
C. Evan Siple, *Research Technician*
Lakishia Smith, *Administrative Secretary*[45]
Loretta Steffy, *Accounting Assistant*
Sarah Stockman, *Predoctoral Research Associate*[46]
Allen Strause, *Machinist*
Maggie Sundby, *Research Technician*
Robert Vary, *Carnegie Science Outreach Educator*
Rafael Villagaray, *Macintosh Support Specialist*
Neil Vranis, *Student Assistant*[47]
Dianne Williams, *Howard Hughes Medical Institute Research Technician III*
Alex Yeh, *Student Assistant*[48]
Geoffrey Zearfoss, *P/T Animal Technician*

Visiting Investigators and Collaborators

Hugo Bellen, *Baylor College of Medicine*
Robert Bittman, *Department of Chemistry and Biochemistry, Queens College of CUNY*
Ian Blair, *Department of Chemistry, University of Pennsylvania*
Vitor Bortolo de Rezende, *Universidade Federal de Minas Gerais, Brazil*
Steven Ekker, *Department of Genetics, Cell Biology, and Development, University of Minnesota Medical School*
Matthias Hammerschmidt, *Max Planck Institute for Immunobiology, Germany*
Samer Hattar, *Department of Biology, The Johns Hopkins University*
Marko Horb, *Institut de Recherches Cliniques de Montréal (IRCM)*
Roger Hoskins, *Lawrence Berkeley National Laboratory*
Hao Jiang, *Laboratory of Molecular Cell Biology and Center of Cell Signaling, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences*
Henry Krause, *Donnelly Centre for Cellular and Biomolecular Research, University of Toronto, Canada*
Steven Leach, *Department of Surgery, Division of Surgical Oncology, The Johns Hopkins University School of Medicine*
Li Ma, *Laboratory of Molecular Cell Biology and Center of Cell Signaling, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences*
Cecilia Moens, *Fred Hutchinson Cancer Research Center*
Karen Oogema, *European Molecular Biology Laboratory, Germany*
Michael Pack, *Department of Medicine, University of Pennsylvania*
Michael Parsons, *Departments of Surgery and Oncology, The Johns Hopkins University School of Medicine*
John Rawls, *Department of Cell and Molecular Physiology, University of North Carolina*
Karen Reue, *Human Genetics and Medicine, David Geffen School of Medicine at the University of California, Los Angeles*
Gerald M. Rubin, *Howard Hughes Medical Institute, Janelia Farm Research Campus*
Didier Stainier, *University of California, San Francisco*
Bernard Thisse, *Department of Cell Biology and the Morphogenesis and Regenerative Medicine Institute, University of Virginia*
Christine Thisse, *Department of Cell Biology and the Morphogenesis and Regenerative Medicine Institute, University of Virginia*
Junqi Zhang, *Microbiology Department, Shanghai Medical College Fudan University*

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[1]From October 1, 2010
[2]To July 31, 2010
[3]From April 5, 2011
[4]From April 12, 2011
[5]From January 10, 2011
[6]To June 30, 2011
[7]From November 1, 2010
[8]To August 15, 2010
[9]From April 20, 2011
[10]From August 30, 2010
[11]To July 12, 2010
[12]From July 1, 2010
[13]From June 15, 2011
[14]From March 1, 2011
[15]From September 29, 2010
[16]To June 30, 2011
[17]From October 1, 2010
[18]From September 15, 2010
[19]From May 2, 2011
[20]To June 30, 2011
[21]To May 1, 2011
[22]To April 20, 2011
[23]From May 23, 2011
[24]To November 30, 2010
[25]To July 1, 2010
[26]From May 23, 2011
[27]From October 15, 2010
[28]To September 23, 2010
[29]To September 30, 2010
[30]To August 19, 2010
[31]To July 31, 2010
[32]To July 31, 2010
[33]To August 31, 2010
[34]From September 8, 2010
[35]To August 31, 2010
[36]To November 15, 2010
[37]From January 19, 2011
[38]To August 31, 2010
[39]To August 31, 2010
[40]From August 11, 2010
[41]From May 31, 2011
[42]To August 13, 2010
[43]To August 31, 2010
[44]To January 15, 2011
[45]From July 1, 2010
[46]To August 31, 2010
[47]To August 31, 2010
[48]To July 31, 2010

Geophysical Laboratory

Staff Scientists

George D. Cody
Ronald E. Cohen
Yingwei Fei
Marilyn L. Fogel
Alexander F. Goncharov
Robert M. Hazen
Russell J. Hemley, *Director*
Wesley T. Huntress, Jr., *Director Emeritus*
T. Neil Irvine, *Emeritus*
Ho-kwang Mao
Bjørn O. Mysen
Douglas Rumble III
Anat Shahar
Andrew Steele
Viktor V. Struzhkin

Senior Scientists and Visiting Investigators

Reinhard Boehler, *Max Planck Institute for Chemistry, Germany, EFree*
Dudley R. Herschbach, *Harvard University*
Charles T. Prewitt, *University of Arizona*
Dimitri A. Sverjensky, *The Johns Hopkins University*
Takamitsu Yamanaka, *Osaka University, Japan*

Research Scientists

Muhetaer Aihaiti, *ONR, CDAC*
Constance M. Bertka, *Program Director, DCO*[1]
Nabil Z. Boctor, *NASA, NASA Astrobiology Institute (NAI)*
Xiao-Jia Chen, *DOE*
Dionysis I. Foustoukos, *NSF*
Mihaela Glamoclija, *AMASE*
Malcolm Guthrie, *Chief Scientist, EFree*
Valerie Hillgren, *NASA*
Qi Liang, *CVD Diamond*
Jinfu Shu, *HPCAT, Carnegie*[2]
Maddury Somayazulu, *CDAC*
Timothy Strobel, *NSF*[3]
Chih-Shiue Yan, *CVD Diamond, NSF, Carnegie*
Chang-Sheng Zha, *CDAC*

GEOPHYSICAL LABORATORY Front row (left to right): John Armstrong, Yufei Meng, Reinhard Boehler, Joe Lai, Danielle Appleby, Morgan Phillips, Paul Goldey, Renbiao Tao, Susana Mysen, Marilyn (Helen) Venzon, Russell Hemley, Anat Shahar, George Cody, Robert Hazen, Andrew Steele, Alexander Goncharov, Verena Starke. Second row: Liuxiang Yang, Elissaios Stavrou, Valerie Hillgren, Takaki Muramatsu, Douglas Allen Dalton, Dyanne Furtado, Sami Mikhail, Lauren Cryan, Andrea Mangum, Stephen Gramsch, Ronald Cohen, Timothy Strobel, Dina Bower, Karyn Rogers, Bjørn Mysen. Third row: Daniel Hummer, Shohei Ohara, Ying Wang, Yoko Kebukawa, Stephen Hodge, Derek Smith, Amol Karandikar, Katherine Crispin, Victor Lugo, Takamitsu Yamanaka, Nabil Boctor, Jinfu Shu, Muhetaer Aihaiti, Trong Nguyen, Vincenzo Stagno, Roxane Bowden. Back row: Oleksandr Kurakevych, Craig Schiffries, Mihaela Glamoclija, Kateryna Klochko, Dionysis Foustoukos, Codi Lazar, Douglas Rumble, Shaun Hardy, Duck Young Kim, Neil Irvine, Felix Krasnicki, Adrian Villegas-Jimenez, Ileana Perez-Rodriguez, Celia Dalou, Stephen Coley, Merri Wolf, Gefei Qian, Chi Zhang.

NSF REU Program Director and CDAC Laboratory Manager
Stephen A. Gramsch[4]

High Pressure Collaborative Access Team (HPCAT), High Pressure Synergetic Center (HPSynC) at the Advanced Photon Source (APS), Argonne National Laboratory, Chicago, IL; National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory, Upton, NY; Joint Institute for Neutron Sciences (JINS) Spallation Neutron Source (SNS) at Oak Ridge National Laboratory, Oak Ridge, TN; and Lujan Neutron Scattering Center (LANSCE) at Los Alamos National Laboratory, Los Alamos, NM
Wing-Shing Au, *Beamline Associate, HPCAT*[5]
Maria Baldini, *Research Scientist, HPSynC*[6]
Alaina Beres, *Summer Intern, HPCAT*[7]
Arunkumar S. Bommannavar, *Beamline Control Scientist, HPCAT*
Paul Chow, *Beamline Scientist, HPCAT*
Yang Ding, *Beamline Scientist, HPSynC*
Cindy Doran, *Administrative Assistant, HPSynC*
Richard Ferry, *Technician, HPSynC*
Rong Huang, *Research Scientist, HPCAT*[8]
Xiaojing Huang, *Postdoctoral Associate, HPSynC*[9]
Daijo Ikuta, *Beamline Associate, HPCAT*
Georgios Karotsis, *Postdoctoral Associate, SNS*[10]
Curtis Kenney-Benson, *Beamline Associate, HPCAT*
Svetlana Kharlamova, *Postdoctoral Associate, HPSynC*[11]
Lingping Kong, *Predoctoral Associate, HPSynC*[12]
Yoshio Kono, *Research Scientist, HPCAT*[13]
Katherine Lazarz, *Summer Intern, HPCAT*[14]
Bing Li, *Predoctoral Associate, HPSynC*
Fangfei Li, *Postdoctoral Associate, HPSynC*[15]
Zhijun Lin, *Research Scientist, LANSCE*[16]
Zhenxian Liu, *Beamline Scientist, NSLS*
Ho-kwang Mao, *Executive Director, HPCAT*[17]
Qiang Mei, *Postdoctoral Associate, HPCAT*[18]
Yue Meng, *Beamline Scientist, HPCAT*
Veronica O'Connor, *Office Manager, HPCAT*
Changyong Park, *Beamline Scientist, HPCAT*
Dmitry Popov, *Beamline Scientist, HPCAT*
Eric Rod, *Beamline Technician, HPCAT*
Olga Shebanova, *Postdoctoral Associate, HPCAT*[19]
Guoyin Shen, *Director, HPCAT*[20]
Stanislav Sinogeikin, *Beamline Scientist, HPCAT*
Jesse Smith, *Postdoctoral Associate, HPCAT*[21]
Erik Wang, *Summer Intern, HPCAT*[22]
Junyue Wang, *Postdoctoral Associate, HPSynC and ANL*
Lin Wang, *Research Scientist, HPSynC*
Yuming Xiao, *Beamline Scientist, HPCAT*[23]
Wenge Yang, *Director, HPSynC*[24]
Kirill Zhuravlev, *Postdoctoral Associate, GSECARS, APS*[25]

Postdoctoral Fellows and Postdoctoral Associates
David M. Baker, *Postdoctoral Associate, NSF*[26]
Dina Bower, *NAI Fellow*
Henderson James Cleaves II, *Visiting Investigator, NASA and NAI*
D. Allen Dalton, *Postdoctoral Associate, CDAC and NSF*
Liwei Deng, *Carnegie Fellow*[27]
Floyd Fayton, Jr., *Postdoctoral Associate, NSF CMG, ONR*[28]
Weifu Guo, *Carnegie Fellow*[29]
Sanchayan Neal Gupta, *NAI Fellow*[30]

Kadek Hemawan, *Postdoctoral Associate, CDAC, WDLP*[31]
Daniel Hummer, *Carnegie Fellow*
Yoko Kebukawa, *Carnegie Fellow, NAI*[32]
Svetlana Kharlamova, *Postdoctoral Associate*[33]
Kateryna Klochko, *Postdoctoral Associate, NAI and NSF*
George Lazar, *Carnegie Fellow*[34]
Yufei Meng, *Postdoctoral Associate*
Lane Nixon, *Postdoctoral Associate, ONR*[35]
Shohei Ohara, *Postdoctoral Associate, NSF*
Julius Ojwang, *Carnegie Fellow*[36]
Dominic Papineau, *Postdoctoral Associate, NSF*[37]
Robert Potter, *Postdoctoral Associate, DOE*[38]
Christopher Seagle, *Carnegie Fellow*
Timothy Strobel, *Carnegie Fellow, NSF*[39]
Ying Wang, *Carnegie Fellow*
Liuxiang Yang, *Postdoctoral Associate, EFree, Carnegie*[40]
Chi Zhang, *Carnegie Fellow*[41]
Li Zhang, *Postdoctoral Associate, NASA*

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Charlene Estrada, *Predoctoral Fellow, NSF*
Patrick L. Griffin, *Research Assistant, Predoctoral Associate, Keck Foundation, DCO*[42]
Amol Karandikar, *Predoctoral Associate, EFree*
Namhey Lee, *Predoctoral Fellow, The Johns Hopkins University*
Joseph Rodriguez, *Predoctoral Associate, NAI*[43]
Derek Smith, *Predoctoral Fellow, Dartmouth College*[44]
Verena Starke, *NASA Marshall Space Flight Center*
Renbiao Tao, *Predoctoral Associate, NSF*[45]

College Interns

Kelare Aihaiti, *Old Dominion University*[46]
Alaina Beres, *Elmhurst College*[47]
Collin Black, *University of Connecticut*[48]
Alyssa Frederick, *Lab Assistant, Research Assistant, American University*[49]
Thomas Hittinger, *Howard University*[50]
Yasmin Kadry, *Howard University*[51]
Stevia Morawski, *Lab Assistant, American University*[52]
Olaoluwa Omotosho, *Howard University*[53]

Summer Scholar Interns (Summer 2011)

Katherine Ames, *University of Delaware*
Ari Benjamin, *Williams College*
Kevin Hernandez, *California State University-Sacramento*
Tau Liu, *Howard Community College*
Julia Vidonish, *University of Chicago*

High School Interns

Justin Chang, *Montgomery Blair High School*[54]
Jessica Garland, *Sidwell Friends School*[55]
Thomas Gramsch, *Lake Braddock High School*[56]
Katherine Jin, *Montgomery Blair High School*[57]
Lori Kaufman, *Montgomery Blair High School*[58]
Winston Liu, *Montgomery Blair High School*[59]
Paola Sofia Palacios, *Montgomery Blair High School*[60]
William Qian, *Thomas Jefferson High School for Science and Technology*[61]
Maimon Rose, *Melvin J. Berman Hebrew Academy*[62]

Supporting Staff

Danielle J.-H. Appleby, *Assistant to the Director, Departmental and Institutional Affairs*
John Armstrong, *Microbeam Specialist*
Maceo T. Bacote, *Building Engineer*[63]
Gary A. Bors, *Building Engineer*[64]
Roxane Bowden, *Lab Manager, Stable Isotope Facility*
Stephen D. Coley, Sr., *Instrument Shop Supervisor*
Lauren Cryan, *DCO Program Assistant*[65]
Roy R. Dingus, *Facility Manager*[66]
Pablo D. Esparza, *Maintenance Technician*[67]
Dyanne Furtado, *Staff Accountant*
Christos G. Hadidiacos, *Electronics Engineer*
Shaun J. Hardy, *Librarian*[68]
Stephen Hodge, *Instrument Maker*
Garret W. Huntress, *Systems Administrator, Systems Developer*
William E. Key, *Building Engineer*[69]
Szczesny (Felix) Krasnicki, *CVD Diamond Senior Engineer*
Joseph Lai, *CVD Diamond Lab Manager*
Jeff Lightfield, *Controller*
Victor Lugo, *Instrument Maker*[70]
Andrea Mangum, *DCO Program Associate*[71]
Quintin Miller, *Building Engineer Apprentice*[72]
Fabian Moscoso, *Building Engineer Apprentice*[73]
Susana Mysen, *EFree Project Administrator*
Trong T. Nguyen, *Assistant Controller*
Morgan D. Phillips, *Assistant to the Director, Science and CDAC*
Scott Price, *Electronics Specialist*
Gefei Qian, *Systems Administrator*
Pedro J. Roa, *Maintenance Technician*[74]
Haiyun (Kevin) Shu, *CVD Diamond Technician*
Helen Venzon, *Accounts Payable Specialist*
Merri Wolf, *Library Technical Assistant*[75]
Pamela L. Woodard, *Web/Departmental Assistant*
Thomas Yu, *CVD Diamond Technician*

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Richard Becker, *Army Research Laboratory*
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Andrew J. Campbell, *University of Maryland*
Razvan Caracas, *Université de Lyon, École Normale Supérieure de Lyon, France*
Laura Carmody, *University College London, U.K.*
Paul Carpenter, *Washington University*
Jennifer Ciezak, *U.S. Army Research Laboratory, Aberdeen Proving Grounds*
Henderson James Cleaves II, *NASA*
Nicole DeBond, *Memorial University, Newfoundland, Canada*
Mariana Derzsi, *University of Warsaw, Poland*
Joseph Feldman, *U.S. Naval Research Laboratory*
Thomas Fitzgibbons, *Pennsylvania State University*
Christopher Florian, *University of Colorado at Boulder*
Christopher Freeman, *University of Alabama at Birmingham*
Marc Fries, *NASA JPL*
Alexander Gavriliuk, *Institute for High Pressure Physics, Russia*
Jennifer Girard, *Florida International University*
Wojciech Grochala, *University of Warsaw, Poland*
Brent Grocholski, *Massachusetts Institute of Technology*
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Pierre-Eymeric Janolin, *École Centrale Paris, France*
Xiulan Jiang, *Jilin University, PR China*
Seiji Kamada, *Tohoku University, Japan*
Chi-Chang Kao, *NSLS, Brookhaven National Laboratory*
Kiho Kim, *American University*
Anton Kolesnikov, *Moscow State Academy of Fine Chemical Technology, Russia*
Atsushi Kyono, *University of Tsukuba, Japan*
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Chad Lane, *Memorial University, Newfoundland, Canada*
Peter Lazor, *Uppsala University, Sweden*
Jung-Fu Lin, *University of Texas at Austin*
Qiong Liu, *Peking University, PR China*
Konstantin Lokshin, *University of Tennessee*
Xuan Luo, *Unaffiliated*
Mohammad Mahmood, *Howard University*
Murli Manghni, *University of Hawaii*
Matteo Masotta, *University of Rome, Sapienza, Italy*
Charles Meade, *RAND Corporation*

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Stewart McWilliams, *Howard University*
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Lisa Monaco, *Marshall Space Flight Center*
Amy Morrow, *Stanford University*
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Balazs Sipos, *Oak Ridge National Laboratory*
Mahmooda Sultana, *NASA Goddard Space Flight Center*
Michelle Thompson, *Royal Ontario Museum, Toronto, Canada*
Jack Tossell, *University of Maryland*
Chris Tulk, *Oak Ridge National Laboratory*
Douwe van Hinsbergen, *University of Oslo, Norway*
Willem van Westrenen, *Vrije University, The Netherlands*
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Zsolt Jenei, *Lawrence Livermore National Laboratory, HPCAT*
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Zhu Mao, *University of Texas at Austin, HPCAT*
Brian Mattern, *Washington State University, HPCAT*
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Jeffrey Montgomery, *University of Alabama at Birmingham, HPCAT*
Jorge Munoz, *California Institute of Technology, HPCAT*
J. Mustfeldt, *University of Tennessee, NSLS*
Hu Dung Nguyen, *Delft University of Technology, HPCAT*
Zhihua Nie, *Northern Illinois University, HPCAT*
H. Okamura, *Kobe University, NSLS*
K. Otsuka, *Yale University, NSLS*
Jonpierre Paglione, *University of Maryland, HPCAT*
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Jeffrey Pigott, *Ohio State University, HPCAT*, *NSLS*
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Gopi Samudrala, *University of Alabama at Birmingham, HPCAT*
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Adam Schwartz, *Lawrence Livermore National Laboratory, HPCAT*
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Yingxia Shi, *Stanford University, HPCAT*
Dan Shim, *Massachusetts Institute of Technology, HPCAT*
Adam Simon, *University of Nevada, Las Vegas, HPCAT*
Hillary Smith, *California Institute of Technology, HPCAT*
Emmanuel Soignard, *Arizona State University, HPCAT*
Yang Song, *University of Western Ontario, HPCAT*
Gerald Stevens, *National Security Technologies, HPCAT*
Brandon Stewart, *University of Nevada, Las Vegas, HPCAT*
Hongjin Tan, *California Institute of Technology, HPCAT*
Elizabeth Tanis, *University of Nevada, Las Vegas, HPCAT*
Sarah Thomas, *University of Alabama at Birmingham, HPCAT*
Sarah Tolbert, *University of California, Los Angeles, HPCAT*
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T. Tyson, *New Jersey Institute of Technology, NSLS*
Cayman Unterborn, *Ohio State University, HPCAT*
Nenad Velisavjlevic, *Los Alamos National Laboratory, HPCAT*, *NSLS*
José Vieira Leitao, *Delft University of Technology, HPCAT*
Yogesh Vohra, *University of Alabama at Birmingham, HPCAT*
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X. Wang, *Brookhaven National Laboratory, NSLS*
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Samuel Weir, *Lawrence Livermore National Laboratory, HPCAT*
Jennifer Wojno, *University of Nevada, Las Vegas, HPCAT*
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Junjie Wu, *Chinese Academy of Sciences, HPCAT*
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Miao Xie, *University of California, Los Angeles, HPCAT*
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Jinlong Zhu, *Los Alamos National Laboratory, HPCAT*
Pavel Zinin, *University of Hawaii, HPCAT*
Bo Zou, *Jilin University, HPCAT*

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[1] To January 28, 2011
[2] Incorrectly represented last year
[3] From October 1, 2010
[4] To August 31, 2010; DOE Program/ Departmental Outreach Coordinator from September 1, 2010
[5] To January 17, 2011
[6] From January 10, 2011
[7] From June 8, 2010
[8] From January 10, 2011, to April 8, 2011
[9] From February 9, 2011
[10] From February 1, 2011
[11] From July 1, 2010, to February 28, 2011
[12] From October 19, 2010
[13] From April 1, 2011
[14] From May 2, 2011
[15] From September 15, 2010
[16] From August 1, 2010, to March 11, 2011
[17] From July 1, 2010
[18] To January 4, 2011
[19] To August 31, 2010; Visiting Investigator from September 1, 2010
[20] From July 1, 2010
[21] From April 1, 2011
[22] From June 20, 2011
[23] Incorrectly represented last year
[24] From July 1, 2010
[25] To April 15, 2011
[26] To January 14, 2011; Visiting Investigator from January 17, 2011
[27] From October 4, 2010
[28] From January 3, 2011
[29] To April 30, 2011
[30] To August 31, 2010
[31] From July 1, 2010
[32] To June 7, 2011; JSPS Fellow from June 8, 2011
[33] From March 1, 2011
[34] From January 4, 2011
[35] From January 3, 2011
[36] To June 30, 2011
[37] To December 31, 2010
[38] From July 1, 2010
[39] To September 30, 2010; Research Scientist from October 1, 2010
[40] From October 12, 2010
[41] From September 7, 2010
[42] To May 31, 2011; from June 1, 2011
[43] From June 23, 2011
[44] From September 1, 2010
[45] From February 22, 2011
[46] To August 13, 2010
[47] To August 6, 2010
[48] From May 16, 2011
[49] From September 29, 2010, to February 27, 2011; from February 28, 2011
[50] To August 31, 2010
[51] To August 31, 2010
[52] From September 29, 2010, to December 31, 2010
[53] To August 31, 2010
[54] From June 1, 2011
[55] From June 2011
[56] To August 31, 2010
[57] From July 15, 2010, to August 14, 2010
[58] From June 20, 2011
[59] To April 1, 2011
[60] From May 3, 2011, to May 31, 2011
[61] To August 31, 2010
[62] From May 2, 2011
[63] Joint appointment with DTM
[64] Joint appointment with DTM
[65] To February 28, 2011; DCO Program Associate from March 1, 2011
[66] Joint appointment with DTM
[67] Joint appointment with DTM
[68] Joint appointment with DTM
[69] Joint appointment with DTM
[70] From August 16, 2010
[71] To February 28, 2011; DCO Program Manager from March 1, 2011
[72] Joint appointment with DTM; From April 1, 2011
[73] Joint appointment with DTM; To February 3, 2011
[74] Joint appointment with DTM
[75] Joint appointment with DTM

GLOBAL ECOLOGY Front row (left to right): David Knapp, Kelly McManus, Dana Chadwick, Monalisa Chatterjee, Yuntao Zhou, Naoia Williams, Jan Brown, Tuai Williams, Evana Lee, Dahlia Quist, Kyla Dahlin, Yoichi Shiga. Second row: John Griffin, Chris Anderson, Kris Ebi, Robin Martin, Loreli Carranza-Jimenez, Julia Pongratz, Katharine Ricke, Lee Love-Anderegg, Hulya Aksoy, Linda Longoria, Rumi Asano, Susan Cortinas, Ismael Villa, Kathi Bump, Ken Caldeira. Third row: Joe Mascaro, Joe Berry, Anna Michalak, Greg Asner, Aravindh Balaji, Mark Higgins, John Clark, Rebecca Hernandez, Jean Baptiste Feret, Matt Colgan, Marion O'Leary, Katherine Marvel, Long Cao, Shane Easter, Kenny Schneider, Vineet Yadav, Ben Kravitz, Michael Mastrandrea, Larry Giles, Eric Kissel, Katharine Mach, Abhishek Chatterjee, Aaron Strong, Bill Anderegg, Jennifer Johnson, Todd Tobeck, Michael Dini, Chris Field, Ty Kennedy-Bowdoin.

Global Ecology

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Kenneth Caldeira
Christopher B. Field, *Director*
Anna Michalak[1]

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Steven Davis, *Stanford University*
Jean-Baptiste Feret, *Université Paris-Diderot, Paris*
James Kellner, *University of Georgia*[3]
Ben Kravitz, *Rutgers University*[4]
Shaun Levick, *University of Witwatersrand, Johannesburg, South Africa*[5]
Scott Loarie, *Duke University*
Katharine Mach, *Stanford University*[6]
Robin Martin, *University of Colorado*
Joseph Mascaro, *University of* Wisconsin[7]
Julia Pongratz, *Max Planck Institute of Meterolog, Germany*
Kenneth Schneider, *Hebrew University of Jerusalem*
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Jennifer Johnson, *Stanford University*
Kelly McManus, *Stanford University*[10]
Alex Nees, *Stanford University*
Adam Wolf, *Stanford University*[11]

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Mona Houcheime, *Laboratory Technician*[18]
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Stephanie May, *Intern*[20]
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Marion O'Leary, *Senior Advancement Consultant*
Guayana Paez-Acosta, *Program Coordinator*[23]
Alexandra Santiago, *Laboratory Technician*[24]
Kevin Smith, *Laboratory Technician*[25]
Todd Tobeck, *Laboratory Manager*
C. Parker Weiss, *Laboratory Technician*

[1] From June 1, 2011
[2] To October 30, 2010
[3] To January 7, 2011
[4] From June 1, 2011
[5] To September 29, 2010
[6] From July 1, 2010, to April 30, 2011
[7] From July 1, 2010
[8] To October 30, 2010
[9] From September 1, 2010
[10] From September 1, 2010
[11] To October 15, 2010
[12] From February 28, 2011
[13] From July 1, 2010
[14] From May 24, 2011
[15] From November 1, 2011
[16] From July 6, 2010
[17] From September 27, 2010, to March 1, 2011
[18] To April 15, 2011
[19] From February 28, 2011
[20] From March 4, 2010
[21] From November 1, 2010
[22] From May 3, 2010, to August 31, 2010
[23] To June 17, 2011
[24] From August 16, 2010, to March 15, 2011
[25] To May 31, 2011

The Observatories

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Juna Kollmeier
Patrick McCarthy
Andrew McWilliam
John Mulchaey
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Eric Persson
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Joshua Simon[3]
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Andy Monson, *Postdoctoral Associate*
Eric Murphy, *Postdoctoral Associate*[10]
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Ryan Quadri, *Hubble Fellow*[7]
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Miguel Roth, *Director, Las Campanas Observatory*

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Gaston Folatelli, *Postdoctoral Fellow*
Shane Walsh, *AAO Magellan Fellow*

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Nidia Morrell, *Visiting Scientist*

Support Scientist

David Murphy, *Instrument Scientist*

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Arash Farahani, *Enclosure Engineer*[17]
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Keith Raybould, *Project Manager*[21]
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Amnon Talmor, *Project Engineer*
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Charmeen Wing, *Joint Development Officer*

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Supporting Staff, Pasadena

Alan Bagish, *Las Campanas Observatory Engineer*
Christoph Birk, *Data Acquisition Programmer*
Jerson Castillo, *Instrument Maker*
Ken Clardy, *Programmer*
Paul Collison, *Computer Systems Manager*
Jorge Estrada, *Electronics Technician*
John Grula, *Head Librarian, Information Services/Publications Manager*
Tyson Hare, *Mechanical Engineer*
Earl Harris, *Shipping and Receiving Specialist*
Silvia Hutchison, *Assistant to the Director*
Ayako Jinno-Kanayama, *Financial Accountant*[24]
Sharon Kelly, *Senior Buyer*[25]
Vincent Kowal, *Machine Shop Foreperson/ Instrument Maker*
Anthony Lee, *Assistant Business Manager*[26]
Becky Lynn, *Secretary*
Sonia Ochoa, *Purchasing Manager*[27]
Luis Ochoa Ramirez, *Accounts Payable Specialist*
Greg Ortiz, *Assistant, Buildings and Grounds*
Robert Pitts, *Assistant, Buildings and Grounds*
Vgee Ramiah, *Business Manager*
Scott Rubel, *Associate Facilities Manager*
Robert Storts, *Instrument Maker*
Irina Strelnik, *Assistant Business Manager*[28]
Edward Villanueva, *Data Analyst and Programmer*
Valerie Vlahovic, *Financial Accountant*[29]
Gregory Walth, *Data Analyst*
Steven K. Wilson, *Facilities Manager*

Supporting Staff, Las Campanas

Miriel Abarca, *Janitor*
Carolina Alcayaga, *Purchasing Officer*
Ricardo Alcayaga, *Mechanic*
Juan Alfaro, *Magellan Site Maintenance Support*
Hernán Ángel, *Driver/Purchaser*
Jorge Araya, *Magellan Telescope Operator*
Hector Balbontín, *Chef*
Andres Borquez, *Chef*[30]
Jorge Bravo, *Magellan Instrument Specialist*
Juan-Carlos Carrasco, *Driver/Purchaser*
Pedro Carrizo, *Plumber*
Jilberto Carvajal, *El Pino Guard*
Jorge Castillo, *Paramedic*[31]
Pablo Castro, *Telescope Controls Programmer*
Emilio Cerda, *Magellan Electronics Engineer*
Angel Cortés, *Accountant*
Henry Cortés, *Electrician*
José Cortés, *Janitor*
Oscar Duhalde, *Mechanical Technician*
Julio Egaña, *Painter*
Juan Espoz, *Mechanic*
Glenn Eychaner, *Telescope Systems Programmer*
Francisco Figueroa, *Supervisor of Mountain Maintenance*
Carlos Flanega, *Janitor*
Javier Fuentes, *Night Assistant*[32]
Juan Gallardo, *Mechanical Engineer*[3]
Manuel Gamboa, *Assistant Construction*[33]

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Luis González, *Janitor*
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Nelson Ibacache, *Mechanical Assistant*
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Oscar Juica, *Plumber*
Marc Leroy, *Assistant Telescope Engineer*
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Pascual Muñoz, *Chef*[38]
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Hugo Rivera, *Magellan Telescope Operator Controls Programmer*
Javier Rivera, *Paramedic*
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Sergio Vera, *Magellan Telescope Operator*
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Jose Zambra, *Chef*[42]

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Darren DePoy, *Texas A&M University*
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Andrea Dupree, *Harvard-Smithsonian, CfA*
Maria Duran, *University of California, San Diego*
Eiichi Egami, *The University of Arizona*
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Kristen Erickson, *University of Missouri*
Pablo Espinoza, *The University of Arizona*
Juan Espoz, *Universidad de Valparaiso, Chile*
Emilio Falco, *Harvard-Smithsonian, CfA*
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Stuart Folkes, *Universidad de Valparaiso, Chile*
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Cristina Garcia, *Pontificia Universidad Católica de Chile*
Victor Gasho, *The University of Arizona*
Jean Rene Gauthier, *The University of Chicago*
Marla Geha, *Yale University*

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David Gerdes, *University of Michigan*
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Stephen Smee, *The Johns Hopkins University*
Nathan Smith, *The University of Arizona*
Jennifer Sobeck, *The University of Chicago*
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Dennis Zaritsky, *The University of Arizona*

[1] To November 13, 2010
[2] To July 2, 2010
[3] From September 1, 2010
[4] No date provided, title change
[5] To September 30, 2010
[6] From April 1, 2011
[7] From October 1, 2010
[8] To February 28, 2011
[9] To October 18, 2010
[10] From March 17, 2011
[11] To July 19, 2010
[12] To July 31, 2010
[13] To August 20, 2010
[14] To August 31, 2010, now Research Staff Member
[15] From October 5, 2010
[16] To April 29, 2011
[17] From June 18, 2011
[18] From August 11, 2011
[19] From February 24, 2011
[20] From April 11, 2011
[21] From December 6, 2010
[22] From March 21, 2011
[23] To February 15, 2011
[24] To September 15, 2010
[25] From February 15, 2011, formerly Buyer
[26] From October 18, 2010, to April 27, 2011
[27] From August 23, 2010
[28] From June 20, 2011
[29] From August 30, 2010
[30] From October 26, 2010
[31] To June 20, 2011
[32] To May 2, 2011
[33] From January 4, 2011
[34] From April 19, 2011
[35] To April 4, 2011
[36] To May 24, 2011
[37] To June 26, 2011
[38] To July 5, 2011
[39] From January 5, 2011
[40] To June 14, 2011
[41] To November 11, 2010
[42] From February 23, 2011

Plant Biology

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[1]From June 16, 2011
[2]From October 16, 2010, to May 13, 2011
[3]From June 22, 2010, to September 30, 2011
[4]From September 1, 2010, to January 15, 2011
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[6]From January 3, 2011, to May 31, 2011
[7]From February 28, 2011, to March 18, 2011
[8]From August 4, 2010, to October 28, 2010
[9]From September 1, 2010
[10]From March 1, 2011
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[50]From September 20, 2010, to January 23, 2011
[51]From January 24, 2011
[52]From October 4, 2010
[53]To October 1, 2010

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[1]From June 27, 2011
[2]From June 20, 2011
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[17]From November 1, 2010
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[20]From August 16, 2010
[21]To July 31, 2010
[22]From February 2, 2011
[23]Joint appointment with Geophysical Laboratory
[24]To September 30, 2010
[25]From September 13, 2010
[26]From April 1, 2010
[27]To February 3, 2011

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July 1, 2010 - June 30, 2011

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GEOPHYSICAL LABORATORY

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